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PHASE I FINAL ENGINEERING REPORT

SPACE FLIGHT OPERATIONS FACILITY

OMMUNICATION SYSTEMS EVALUATION AND STUDY

PL Contract Number 950261 — 15 January 1963

AC Reference Number 9824 — FR 62-11-104

HUGHES

HUGHES AIRCRAFT COMPANY

GROUND SYSTEMS

FULLERTON, CALIFORNIA

R.O. 63-108

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1.0 INTRODUCTION

The purpose of this report is to provide one document in which there is assembled the results of the engineering effort on Phase I of Contract 950261, Jet Propulsion Laboratory Space Flight Operations Facility Communications Study.

Phase I, which began 9 May 1962, and continued thru 30 November 1962, was the period during which the JPL-SFOF communication system was designed and procurement type specifications prepared. Successive phases pertain to implementation, including installation, check-out, operation, and maintenance. Several Phase II tasks were begun in Phase I, and several Phase I tasks continued into Phase II.

Also included in this report are copies, with discussion and comment, of all study, analysis, and evaluation that was performed, as detailed subtasks, in order to enable preparation of the final design and specifications.

An explanation of mission and functions of the JPL SFOF is given in Section 3.0 and Appendices B and C. Floor plans will be found as figures G-2, 3, 4 at the end of Appendix G, Design Specifications for the closed circuit television system.

SECTION 2.0

SUMMARY OF ACTIVITY AND RESULTS

Appendix A contains the contractual statement of work, major tasks, detailed subtasks, and a tabulation showing their relationships. Progress on the tasks was reported in the Monthly Technical Reports, and is reviewed here. A critical (PERT) path would have flowed through the subtasks in a straightforward sequential manner, as follows: (major tasks are underlined)

Determine Information Exchange Requirements

Evaluate JPL-EPD 68 Design Criteria

<u>Determine Communication Requirements</u>

Evaluate Present System (JPL Terminal)

Evaluate Overseas Transmission Media

<u>Produce Preliminary Design</u>

Examine and Report on Reliability Factors

Examine and Report on Operations Analysis and Human Engineering Factors

Study Future Concepts

Study and Evaluate Available Hardware

Evaluate Prospective Contractors

<u>Produce Final Design</u>

<u>Produce Drawings and Specifications</u>

The Hughes engineers worked as a team in order to speed orientation and understanding of all facets of communications. Individual team members were assigned specific tasks, however, and were held responsible for end of task reports.

After the preliminary design was completed, the engineering was divided by mode, that is, telephone, teletype, public address, closed circuit TV, multiplexing, installation, and technical control.

The preliminary design, after review and comment by JPL, was resubmitted to JPL by subsystem. This resulted in a series of meetings between Hughes and JPL engineers, which led to determination of definite criteria for the final design. It became obvious that functional-type specifications would have to be prepared for all or part of each subsystem in order to take advantage of the best commercially available hardware. This meant that a final design, as such, would be meaningless. Therefore, the final design criteria were converted to specification outlines and work began on preparation of the specification.

Preparation of specifications began in August 1962; initial rough drafts were completed in October and formally submitted to JPL in early November 1962. During November Hughes and JPL engineers reviewed the specifications and final drafts were then submitted to JPL in late November and early December. In November and December the final drafts were again reviewed by Hughes and JPL engineers, then submitted to JPL technical publications department for final printing. See Section 5.0, SPECIFICATIONS, for specific description of activity on each individual specification.

Although not discussed in this report, specific "task numbers" are shown for review of designs and specifications by JPL. Also, numbers were assigned to tasks for review of work by Hughes "consultants." This consulting was not necessary because with the part time addition of reliability, computer, operations research, and human factors engineers to the Hughes team, no other assistance was required.

Two tasks shown in Appendix A: Produce JPL Operational Communications Handbook; and Produce Functional Specification for JPL SFOF design handbook, were not performed because they were added after the contract negotiated and then eliminated after it became clear there would be no time to perform these tasks.

SECTION 3.0

EVALUATION OF PRELIMINARY DESIGNS

3.1 INTRODUCTION

The major task: "Prepare an engineering and evaluation study of JPL's SFOF communication system preliminary designs and technical decisions to recommend applicable revisions and shall ascertain if any additional requirements are necessary," required execution of the following subtasks:

- Determination of Information Exchange Requirements
- Evaluation of Existing System (JPL/SFOC Terminal)
- Evaluation of Existing System (External to JPL/SFOC)
- Determination of Communication Requirements
- Evaluation of JPL EPD-68, Design Criteria for the SFOF
- Determination of Implication of Future Concepts

This section discusses work done on each of the subtasks. Pertinent reports are included as: Appendix B; Information Exchange Requirements, and Appendix C, Communication Requirements.

3.2 GENERAL

Determination of information exchange requirements involved four studies:

- The External (to JPL) Communications Hierarchy
- The Internal (to JPL/SFOF) Communications Hierarchy
- Qualitative Information Exchange Requirements
- Quantitative Information Exchange Requirements

The first three of these studies were completed early during the contract. The fourth was carried sufficiently far to enable completion of the study of communication requirements, then discontinued before it was fully prepared for matrix analysis. This study should be continued at a later date with consideration being given to automation of the information, thus allowing computer printouts of continually updated requirements.

Evaluation of the existing system was divided into two parts:

- JPL/SFOC Terminal
- Facilities External to JPL/SFOC

Evaluation of present terminal required a study and analysis of all communications modes and equipment, and observation of simulated and actual space flight operations. It was not until after the first Mariner operations were observed that communications requirements were fully appreciated and understood.

Analysis and evaluation of circuits external to JPL included the circuits to the DSIF's, AMR and GSFC. This study was short but was necessary in order to comprehend the interface problems at JPL. Recommendations to allow the obtaining of higher data rates with decreased error rates and higher circuit availability have been made.

Determination of communication requirements was based on interviews with JPL engineers and scientists and the study of available documents. This subject is discussed in Section 3.6 and the task final report is included as Appendix C.

Evaluation of JPL EPD-68, SPACE FLIGHT OPERATIONS FACILITY DESIGN CRITERIA, 2 February 1962, has not resulted in a formal document containing an "Evaluation." The reason is that EPD-68 was the main JPL document upon which communications requirements and the preliminary communication system design were based. There is very little material in EPD-68 pertaining directly to communications, but the entire document was used as a basis for communication system design. Rather than an evaluation, there is required an updating to correct specific details, such as room assignments. The philosophy for operation and design, however, is completely valid.

Study and evaluation of future concepts was divided among all the other subtasks, as appropriate. Hence, for the initial design, there is no single formal paper on this subject. Obviously, the near future will provide high speed data communications on a world-wide real-time basis. Phase II studies of final communication system designs will include consideration of the effect of satellite communications and the consequent change of surface facilities to data formats from teletype formats.

3.3 INFORMATION EXCHANGE REQUIREMENTS

3.3.1 INTRODUCTION

In order to adequately evaluate JPL-SFOF communication plans and designs, make recommendations for changes and additions, then design a communication system and prepare specifications for implementation, it was necessary to make 1/ a thorough study of the communications necessary to support space flight operations. This study was Hughes Task: "Determination of Information Exchange Requirements". Included in the work was an analysis and study of SFOF internal and related external hierarchy, and information flow that occurred in preparation for, and during space flight operations. Reference is made to Appendix B which contains the results of the detailed work performed in the execution of this task.

The approach to solution of the problem of determination of information exchange requirements was to perform four consecutive analyses, the last of which could be converted to definite traffic flow by source, sink, mode and quantity. These four steps included the determination of the:

- External Communications Hierarchy
- Internal Communications Hierarchy
- Qualitative Information Exchange Requirements
- Quantitative Information Exchange Requirements

A discussion of each of these studies follows in subsequent paragraphs. Work in the fourth area was only carried to the point where sufficient information was available to design the interim communication system. It may be useful to continue this work during Phase III or IV to assure that future operations can be covered adequately.

3.3.2 GENERAL

Information for development of this task was obtained by interviews, conferences, and discussions with JPL personnel and by study of JPL prepared documents. The original plan for accomplishment was to prepare the first two "hierarchy" studies then proceed directly to determination of COMNEEDS, external and internal, with

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1/ This work is sometimes defined as "determination of communication needs", or COMNEEDS; however, there is less confusion in meaning of terms if this is called "determination of information exchange requirements". The reason for confusion is that the basic communication design is derived from determination of communication requirements, and the term requirements can be defined as either "needs", or a list of required circuits and/or equipment.

emphasis on internal. Only sufficient work was to be done in the external requirements.to allow a better understanding of SFOF interface with external elements. 2/

The first two subtasks were completed on schedule and submitted to JPL for comment at the first monthly technical meeting. Comments received largely concerned the fact that the test director is primarily responsible for coordination of all activity, rather than wholly responsible for all functions, which he in turn delegates to lower echelons.

This entire task is based on information and plans available up to 25 June 1962. It should be completely updated, with emphasis on communications aspects, during Phase II or IV of this project.

3.3.3 JPL-SFOF EXTERNAL COMMUNICATIONS HIERARCHY

The purpose of this study and analysis was to determine all elements external to the SFOF with which the SFOF would exchange information. This included receive only (telemetry) and send only (up-data). These elements were then defined, described, and their functions delineated.

For a detailed presentation of this material, see Appendix B, Part 2.The study consisted of three major sections which are summarized as follows:

Section 1: The first section of the paper presented a chart depicting the preliminary structuring of the SFOF External Communications Hierarchy. The chart was so labeled that the nodes and the connecting links were keyed to the text.

Section 2: This presented a gross specification of the required communications. Some of the areas of discussion were:

- Handover coordination between Test Director, JPL Operations Center at AMR, and the AMR Launch Complex.
- Spacecraft acquisition and injection conditions data.
- Mission coordination between Test Director, JPL Technical Management, and NASA agencies.
- New releases.

2/ The phrase "communications hierarchy" is used to avoid use of the term "organization", which implies superior and various levels of subordinate echelons. For the purpose of communication, an organization does exist, and all switching and routing is based on this. It may be based on command hierarchy, as in a military system, or on geographical or population density factors, as in civilian systems.

- Responsibilities for transmission of commands to the Spacecraft.
- Responsibility for standard and/or non-standard control of the DSIF's.
- Source of DSIF instructions.
- Sources for Spacecraft commands.
- Support of pre-flight tests.
- Transmission of Spacecraft commands.
- Over-all project responsibility.

Section 3: This section attempts to define the functions and/or responsibilities within the external communications hierarchy as defined in Section 1. The specific areas discussed were:

- Test Director
- JPL Technical Management
- AMR Launch Complex
- Related NASA Agencies
- Public Information Agencies
- DSIF Control
- Space Science Areas
- Flight Path Analysis Area
- Spacecraft Performance Analysis Area
- Communications Center
- Central Computing
- DSIF Capabilities
- Spacecraft Assembly Facility
- AMR System Test Facility
- Environmental Test Lab
- Special Test Locations

3.3.4 JPL-SFOF INTERNAL COMMUNICATIONS HIERARCHY

The purpose of this study and analysis was to determine from conferences and available documentation the organization, mission, and functions of all elements making up the planned SFOF. Emphasis of course, was placed on aspects particularly important to communications.

For a detailed presentation of this material, see Appendix B, Part 3. The material is essentially in the form of an organization chart with descriptive text. A summary of the study follows:

A diagram is given to indicate the principal work areas and/or functions involved in the conduct of operations at the SFOF. Concern is with only the internal operations of the system. The chart is constructed with a view to giving some idea of the levels of control exercised at each of the positions.

The accompanying text attempts to describe the functions, responsibilities, and the elemental communications required for the principal areas of the SFOF. The functional/work areas discussed are:

- Operations Control Room
  - Test Director
  - Project Manager
- Operations Area
  - Customer Engineering
- Operational Communications Center
  - Crypto Room
  - Terminal Equipment
- Main Data Processing
  - Central Computer
  - Data Conversion Area
  - Data Clean-up
- DSIF Control
- Space Science Operations Board
  - Display/Analysis Rooms 1 & 2
  - Video Analysis Room
  - Photo-Processing
- Flight Path Analysis
- Spacecraft Performance Analysis
  - Spacecraft Model
- TV Switching and Control
  - Closed-Circuit TV
  - TV Intercom
- Briefing Room
- Gallery
- Public Information Service
  - TV Room

3.3.5 JPL-SFOF QUALITATIVE INFORMATION EXCHANGE REQUIREMENTS

This study was made quickly from available documentation and previous conferences. See Appendix B, Part 4, for detailed study. Its purpose was to set forth some qualitative requirements for the information at each of the SFOF operating areas.

Oral communications were treated as a separate subject. Because of their very nature, it was not possible to predict their content with any accuracy. Instead, a concept was proposed for meeting the necessary oral communications criteria.

The paper was divided into two distinct sections.

Section 1: SFOF Data Requirements. "Data", for the purposes of this paper was defined as that information normally requiring computational processing. It thus excluded general administrative information and most voice traffic.

The first step was to present a chart tracing the actual flow of data through the SFOF. The flow was discussed in terms of three broad categories of data: (1) Real Time; (2) Non-real Time; and, (3) Command.

The second step was to attempt a more specific description of the kinds of data at each of the areas of the SFOF. The areas were taken up on an individual basis. In each case, the basic functions and/or responsibilities associated with the area were first defined. Secondly, the data needed at the position was listed - with an indication of the source. And thirdly, the data initiated at each of the positions was listed, together with the intended receiver(s).

Section 2: Requirements for Oral Communications. It was impossible to predict, with sufficient certainty, the character and the content of the oral communications within the SFOF environment. Typically, they would contain a spectrum of information concerned with:

- verbal attention call-outs.
- work coordination
- personnel assignment
- non-standard operations
- etc. . . . .

Hence, rather than defining content, some criteria for the oral communications nets were suggested.

3.3.6 JPL-SFOF QUANTITATIVE COMMUNICATIONS REQUIREMENTS

The studies and material gathered to 25 June 1962 were used to prepare a table showing sources, sinks, and details of all information transfer. Reference is made to Appendix B, Part 5, for a detailed presentation.

Very basically, the grid evaluation model is simply a "from-to" grid. Senders of the system were used to define the rows; while the receivers defined the columns. In the model specifically for the SFOF, the row identification was the same as the column identification. Within the square defined by a specific sender and a specific receiver, transmissions between the parties (in the indicated direction) are described. Where the sender and the receiver are the same, the space is used to define internal information.

The principal functional areas of the SFOF were used as the sender/receiver nodes. Four information referents were selected to describe the transmissions: (1) Information Class; (2) Signal Type; (3) Data Rate; and (4) Time Slot. Each referent was broken down in terms of a code. The code was then used to make the entries into the grid. Thus, each grid entry had four integers which, with the code list, served to describe the transmission.

It is obvious that the four referents could not possibly give an exhaustive description of each transmission. So, auxiliary information was entered into the cards of a card-file. Each grid-entered transmission had its own card. A fifth number was added to each grid entry to identify the associated card. This number was also used as an index on the card. To enable the retrieval of card-information by receiver and/or sender, these were also used to index the cards.

The accompanying description defined the criteria which were used in the selection of the present referents and the coded break-down. Possibilities were offered for future improvements. Improvement possibilities for card-filing, such as a "Keysort" system, were also proposed.

3.3.7 SUMMARY OF TASK, INFORMATION EXCHANGE REQUIREMENTS

Study and analysis of Information Exchange Requirements was divided into four subtasks consisting of determination of the following: External Communications Hierarchy; Internal Communications Hierarchy; Qualitative Information Exchange Requirements; and Quantitative Information Exchange Requirements. From this, the communications requirements were determined.

There was insufficient time to carry these four studies to the depth of detail really desirable, because the communication system design had to be completed early. The studies were not updated and the fourth one, Quantitative Analysis, was discontinued after sufficient information was available to allow design of the communication system.

Because of the nature and size of the JPL-SFOF, the "initial" communication system design was completed without benefit of a complete quantitative analysis. Before the "final" design of the communications system is completed, all elements of this task should be updated and completed.

No effort is made here to summarize the actual findings of this task because the material is not especially amenable to summarization.

3.4 ANALYSIS AND EVALUATION OF PRESENT JPL SPACE FLIGHT OPERATION COMMUNICATIONS

3.4.1 GENERAL

Analysis and evaluation of JPL communications in support of space flight operations for period from 15 May 1962 through 30 November 1962 was made by all Hughes personnel concerned with this study. This included the conference, intercom, call-director, closed circuit TV, teletype, data, and telewriter subsystems. The study considered actual equipment, circuitry, use by the space flight operations personnel, and operation and maintenance by communications personnel. No effort has been made to formally document this subtask because it would be duplicating documents received from, or on file at, JPL.

Hughes personnel had a limited opportunity to observe actual operations during simulated and actual space flight operations. Observance of these operations was of great assistance in understanding capabilities desired by JPL and determining communication needs that had to be fulfilled. The results of these studies were included in the preliminary design, and most were carried through to the specifications.

The "lab" administrative telephone system was studied to determine its functional and technical relationships to operational communication requirements. During Phase II, the planned CENTREX to be installed by Pacific Telephone and Telegraph Company to serve JPL will be studied to determine interface, operations, and maintenance problems with regard to the SFOF.

3.4.2 SPACE FLIGHT OPERATIONS

Space flight simulation and actual operations were observed during July and August 1962. Certain remarks from Hughes engineers are included here. Most problems related had been resolved by JPL communications personnel by 30 November 1962. Those which had not must await completion of the SFOF before they can be satisfactorily resolved. Pertinent remarks from the observation reports that follow are justification for recommended designs:

Group A

a. Beginning about two hours before launch, the primary function of the main comcenter is to establish all external circuits and assure all internal circuitry is properly connected and operational.

b. Some long distance calls are 4W and some are 2W. The 4W are leased duplex channels and the 2W are regular lines made available by placement of a long distance call. The voice subsystem must be able to handle both types. Because space flight operations are infrequent, it is more economical to place long distance calls than to lease lines. Considerations should be given to pre-engineered circuits.

c. Links of tandem to Joberg reversed by Telco. Therefore it was not known whether routing via London or routing skipping London was defective. This is important because it allows an estimate of probable outage time.

d. Teletype-borne data was stopped on line 68 from Canaveral so that JPL could "change tape." This may be a major problem when an effort is made to place all teletype operations with the users.

e. At about T-5 the communications supervisor must state status of all circuits. If Joberg circuits are out, then launch may be postponed. During certain times of the day, when propagation causes intermittent outages, launch should not be delayed. This means that the reason for outage should be known, and a "no-go" given only if Joberg circuits are out because of a non-propagation failure.

f. Suggest WWV be monitored to get information on propagation.

g. Four time periods can be considered:

   (1) Up to "T" without delays

   (2) After "L" (assume T = L) without trouble

   (3) Up to "T" with delays

   (4) After L with trouble

   I was fortunate in that I was able to observe space flight operations in each of these time periods.

h. During the period up to T, if there are no delays, then all is serene and there is no activity in the OC.

i. During the period up to T, if there are delays, then there are conferences within the OC and between the OC and Cape Canaveral. For example, a change in orbital controlling factors because of delayed launch. These conferences are very important, must bring together everyone involved, and decisions must be quickly disseminated.

j. During the period after L, if all goes well, there are no problems. Cape and downrange tracking stations send data to JPL for first orbit determination. Predictions are then transmitted to the DSIF's.

k. During the period after L, if trouble develops, there is the same need for conferences as related above.

l. Regarding a delay of 24 hours, to fire Mariner II instead of Mariner I because of a malfunction in I, it was necessary to assure all DSIF's could accommodate change within 24 hours, and be fully operational. This proved to be possible, but left all DSIF's without spare equipment on proper frequency.

m. If launch is cancelled, aborted, or rescheduled, Test Director must determine next schedule and assure himself that all personnel know of this before being dismissed. Actually, elements are secured section by section.

n. A PA system is essential to keep all personnel informed. Entry of this system by TD should be at 2 to 4 db above normal level.

o. Determination of faults and remedies or alternate courses of action require conferences in real time with immediate dissemination of decisions. These conferences are important and all factors must be considered.

p. DSIF manager positively needs direct voice contact with each (all) DSIF in order to obtain information for use in the decision-making process.

q. It seemed the major problem was to sustain communications, and all personnel were mixed up in it. Needed is auto monitoring of circuits.

r. Consider teleprompter type display of Table ''X'' of operations plan. Or, if computer space is available, consider storage of all items and display them as "NOW, " ''NEXT, " ''READY. " Any item could be called out by number for examination or correction. (This is similar to TV station master control.) This approach could be expanded to light warning lights on test director and other consoles. To operate item (if appropriate), other members of operations could operate go-no-go switches which would signal status to test director.

<u>Group B</u>

a. Communications console personnel become overloaded during ''failure and fix'' situations because they had to buffer, format, and pass (verbally) all information concerning the new communications configuration resulting from the fix. This typically results in separate calls to AMR, TD, CCF, Info. Coord. and tracking director (also sometimes directly to DSIF's). An automatic means of passing this information as it is generated would significantly relieve this problem.

b. During the operation, several patching configurations are required. At present, repatching is accomplished line by line. This takes rather a long time and typically occurs at times during which a great deal of critical information must be gathered and assimilated by the Communications Center in order to decide exactly when repatching is to be implemented. Simplification of the manual operations necessary to repatching would contribute to alleviation of the overload conditions during these critical periods.

c. In summary, given that the above statements of problem areas are valid, a means of rapidly changing patching configurations, modifying these configurations on a point-by-point basis, and automatically passing current patching information would be expected to increase the load handling capability of the Communications Center.

d. The communications console now being installed should assist in allowing more rapid and accurate repatching. However, there may be some problems associated with the use of a keyboard matrix as large as 25 x 25 which has indicators not on the keys, but only along the edges. During heavy load conditions, when operators are under stress, this may contribute to periodic errors. It would, therefore, appear worthwhile to consider means of assisting the operator in locating correct intersections. Without major revisions in system philosophy and hardware, means of doing this are somewhat limited. I suggest category groups of rows and columns along with simple line and position indicators on the keys themselves. These help distinguish one row or column of keys from those adjacent, and will reduce error probabilities. It should be noted that this approach may be tried with a minimum investment. "Artist Aid" transfers could be used to mark keys. As implied earlier, this solution is probably less sophisticated and effective than one which might result from a detailed evaluation of the system philosophy underlying the approach to patching. The latter is being accomplished in connection with the SFOF contract. These pages attend only to possibilities of immediate improvement of the present system.

e. The entire patching configurations must be changed several times during the course of a mission; the new configuration is known in advance of the mission; therefore, reduction of the time required for this change would significantly improve system effectiveness. Consideration might be given to making overlays for the keyboard matrix that would guide the repatching process. The overlays would cover the entire keyboard; be located with registration pins and have holes cut in them through which keys are depressed. The overlays would be placed over the keyboard at the start of the repatching process, buttons depressed where openings existed, and then the overlay removed. This would remove the necessity to locate each key, and should reduce the probability of error to zero. After removal of the overlay, any necessary modifications to the basic configuration could be made. A refinement of this notion would consist of constructing an overlay in which key openings can be open or closed rather than being static cutouts. With this the repatching configuration could be preprogrammed as late as a few minutes prior to actual repatching, and on the basis of current communications conditions.

Group C

a. The primary communications problem seems to stem from the fact that everyone wants to know what is going on everywhere, all the time. This was not unreasonable with the original small operation; but as more people and facilities are tied in, it soon becomes impractical. More delegation of authority and responsibility with communications more nearly restricted to direct functional relationships seems desirable.

b. Considerable confusion arose in attempting to coordinate TTY data lines and the page printers in the sub-com center in Bldg. 125. Some scheme should be devised such that the closed-circuit TV camera viewing copy from a particular data source (say DSIF "A" telemetry) be always available on the same switch position (say switch No. 1) for the operator at the TV monitor. In this manner, switch No. 1 at the monitor console could be labelled "DSIF 'A' Telemetry" and the operator would always press that button to view whatever was available from that particular data source.

c. Much time was wasted keeping personnel advised of communications status. Status board display should be automatically set up by actions in Communications Center. Why does AMR need status of como to DSIF's?

d. Poor mechanization of take-up for TTY hard copy in 125 sub-com center. Paper binds, tears, folds, or otherwise gives trouble so that it is not observable on TV.

e. Communications Center (Bldg. 190 TTY) needs at least one spare tape reperforater so that it is not necessary to hold data at source while tape is changed at JPL.

3.4.3 DATA COMMUNICATIONS

A short study of data communications was made. It was determined that there will be no digital data subsystem in the initial design. However, data-phone service may be employed between JPL and AMR, and digital data modems may be used on voice channels of Goldstone-JPL Western Union microwave system. The results of a survey of applicable data modems was made. Results are shown in Table 3.4.3-1. Since the survey, the Bell System has announced data-phone service at 4800 bps, using a phase modulated device similar to the HC-270. Other equipment that should be considered is that of Rixon and Robert Shaw Fulton which provide special parallel-series converters for use between buffers and modems and special multi-parallel channel transmission systems.

The following notes apply to Table 3.4.3-1:

Note 1: Line Characteristics

Atten: 3 db down at 900 cps and 2300 cps
6 db down at 600 cps and 2500 cps

Delay: 1 Msec. or less at 800 cps and 2350 cps
2 Msec. or less at 2700 cps
(All delays with respect to 1500-1700 cps)

Note 2: Line Characteristics

Atten: ± 3 db 900-3200 cps
± 6 db 650-3450 cps

Differential Delay

1.0 msec. 800-3300 cps
1.4 msec. 650-3450 cps

Net Loss (maximum): 20 db

Short Term Variation: 4 db

Note 3: Line Characteristics

Atten: ± 3 db 900-3200 cps
± 6 db 550-3550 cps

Differential Delay

1.0 msec. 800-3300 cps
1.4 msec. 550-3350 cps

Net Loss (maximum): 20 db

Short Term Variation: 5 db

Table 3.4.3.-1 Survey of Characteristics of Data Modems

	Modems	Maximum Speed (Bits/Second)	Price Per Duplex Terminal	Transmission Media	Modulation Method	Circuits	Power	Present Status	Miscellaneous
1.	Western Electric AN/TSQ-36	750	About $30,000 (includes A-D and D-A converter)	Toll Grade Voice Line	AM	Solid State	110V 60 cps	Production Complete	Special design for air defense systems. Each message contains up to 200 bits
2.	Western Electric AN/TYA-13	750	About $ 8,000	Toll Grade Voice Line	FSM	Solid State	110V 60 cps	Prototype Built	Special design to replace AM modem in AN/TSQ-36
3.	Hughes GSG AM Modem	750		Toll Grade Voice Line	AM	Solid State	±16 V.D.C.	In Production	Designed to replace AN/TSQ-36 AM Modes at lower cost
4.	Hughes GSG FSM Modem	750		Toll Grade Voice Line	FSM	Solid State	±16 V.D.C.	Prototype Built	Designed to replace AN/TYA-13 Modes at lower cost
5.	Bell System DATA-PHONE Series 200	1,600	$45/month lease $75 installation	Bell System Switched Lines	AM	Solid State	110 VAC 60 cps 0.1 amp	Available 90 days after order	Leased line not required
6.	Collins TE-210 D2	2,400	$11,000	Schedule 4A Line	Phase Shift	Solid State	110 VAC 47-450 cps 2 amps	In Production	MTBF of 3000 hrs quoted
7.	Hughes Aircraft HC-272	2,400	$25,000	HF Radio	Phase Shift	Solid State	110 VAC 60 cps 6 amps		
8.	LenKurt 26A Datatel	2,400	$ 7,650	Toll Grade Voice Line	FSM	Solid State	115 VAC 60 cps 0.5 amps	Available Sept. 1962	
9.	Rixon SEBIT 24B Modem	2,400	$ 7,500	Special Line (Note 1)	Vestigial Sideband		120 VAC 60 cps 1.0 amps	Available from Stock	Built in scope included in prive MTBF of 7500 hrs quoted
10.	Collins TE-202	3,200	Will quote ($60-150K)	HF Radio	Phase Shift		110 VAC 60 cps 10.2 amps	Special order 5 month delivery	MTBF of 590 hrs based on 40 channel oper
11.	Collins TE-211A-1	4,800	$ 9,000	Special Line (Note 2) for 2400 bits/second Schedule 4A Lines may be used	Phase Shift	Solid State	120 VAC 60 cps 3 amps		MTBF of 1000 hours quoted
12.	Hughes Aircraft HC-270	4,800	$ 9,000	Schedule 5 Line	Phase Shift	Solid State	210 VAC 50-60 cps 0.4 amps		
13.	Collins AN/GSC-4	5,400	Will quote ($50-60K)	Special Line (Note 3)	Phase Shift	Solid State	110 VAC 60 cps 3 amps	Special order 8 months delivery	Militarized
14.	Bendix AN/TYC-3	19,200	$35,800	43.2 Kc carrier cable, Spiral 4 cable		Solid State			R & D Model for U.S. Army. None produced
15.	Bell System DATA-PHONE Series 300	40,800	Will quote (lease only)	TELPAKA or equivalent carrier				Special order	For matnetic tape communication applications

3.5 ANALYSIS AND EVALUATION OF CIRCUITS EXTERNAL TO JPL

3.5.1 INTRODUCTION

It was necessary to make a short study of communication circuits external to the JPL-SFOF in order to fully understand the interface problems and assure consideration is given to all circuit characteristics that could influence design of the SFOF communication system. The factors of primary interest were data rate, error rate, and circuit routing and switching. This section also includes comments on, and recommendations for the improvement of, the long haul communication circuits.

3.5.2 GENERAL

It is apparent that the SFOF initial design must include capabilities to operate with 60 wpm teletype from Australia and South Africa and circuit or message switching facilities for routing of Goldstone and Australian traffic to other NASA centers. Eventually, the Australian and South African circuits will be high speed data, up to video bandwidths, with low error rates, via communication satellites. By that time, or shortly thereafter, the surface communication facilities will have been converted from baudot code to digital data alpha-numeric formats for handling low or high speed data, depending on characteristics of the transmission medium. The SFOF communication system "final" design must provide for ease of modification to accept these advanced modes.

3.5.3 DATA RATES

The JPL-SFOF is primarily interested in two-way data transmission with AMR and the DSIF's. The data rate of a facility is directly related to its bandwidth, and the bandwidth is limited by state of the art employed by the facility and economics. All problems with Goldstone are to be resolved by the lease of wide-band Western Union facilities. Problems with AMR can be resolved by lease of appropriate TELPAK or special facilities.

For communications with Australia and South Africa, it has been necessary to use commercial facilities. This dictates the use of telephone or teletype channels. Telephone channels over these distances and over transmission media used cannot handle digital data rates, derived from ordinary digital data modems at source and sink at rates much greater than teletype speeds. This is because of high frequency radio multi-path smearing and impulse noise of innumerable and many unnecessary tandem links. Teletype facilities are limited in speed by the fact they are early 1940 models with the addition of RCA "ARQ" error detection and correction equipment. Teletype facilities are further limited by the fact that the commercial routes in service are the only routes used. Because of the nature and requirements of future lunar and planetary missions, it is necessary to obtain higher data rates from South Africa and Australia.

It is believed that teletype codes will be abandoned; first for low speed data and then for higher speed data. Communication satellites will probably not be used to relay teletype because of the inherent inefficiency of teletype codes and the ease with which wide-band data can be handled. It is further believed that surface systems will also abandon teletype codes for low speed data. Commercial carriers should be urged to speed up this conversion to include updating of equipment. Three basic improvements are necessary to increase data rates: decrease error rates; increase bandwidth; and abandon teletype codes.

Error rates are discussed in the next section. Obviously, the first gains from decreased error rates should be more accurate data, then additional gains can be applied to increased rates.

On long-haul overseas circuits, the best that can be expected in wider bandwidths is to change from a teletype channel (about one-sixteenth of a voice channel) to the full so-called "3 KC" element of submarine cable and high frequency (HF) twin sideband-suppressed carrier systems. Without special equipment, data rates up to 1200 bps might be expected. HF radio techniques and equipment available and necessary to decrease error rates also serve to materially increase data rates. Such facilities can be used to provide over 4800 bps, depending on the type of terminal equipment used and the characteristics of the ionosphere. Such systems are variable and operate in multiples of 75×2^n up to the limit that the transmission medium can support with acceptable error rate.

A teletype signal has a start and stop signal, used for synchronization, for each five bits of information. If conversion is made to low speed data, with one synchronization bit for 31 information bits, then the efficiency of the system for equivalent bit rates increases from 71% to 97%. Conversion from teletype to low speed data also more readily allows use of computer techniques for error detection and correction.

3.5.4 RELIABILITY AND ERROR RATES

The problem is whether or not the circuit is operational; and if the circuit is operational, what the error rate is. Two axioms of reliability are applicable. First, as the hierarchial pyramid of component, subsystem, and system is ascended, the factor of human engineering becomes more evident; then, for innumerable circuits in tandem, the resulting reliability is the product of the reliability figures of each system.

A circuit may be "in," or "out" if there is a human or equipment failure; or if there is a HF radio link in the circuit, it may not support transmission at an acceptable error rate. The solution to this problem is the use of redundant circuits, or links, to include equipment, transmission media, and transmission paths. In the case of a radio link, circuit outages may run from 5-30% even if optimum frequencies are always used. (This means changing frequencies two to four times each 24 hours. Studies made by Hughes personnel working on Surveyor indicate outages due to human error are almost as frequent and long as those due to HF path fades.) Frequency changes will not always re-establish a circuit; instead, geographical alternate routing is necessary. To maintain high circuit reliability, the least number of tandem systems should be used; and HF radio should be avoided.

The major problem with HF radio links is multipath distortion. Equipment is readily available to overcome the multipath problem and also provide data rates from 1800 bps up to 4800 or 5400 bps. This requires a full HF channel, 10 KC's or more wide, as a frequency stepping technique is used. It should be possible to get the necessary international cooperation for frequency clearance for lunar and planetary missions. Another problem with HF circuits is fading and blackout due to ionospheric disturbances. Some of the fading can be predicted by several hours or days. During mission periods the common carrier should furnish continuous short term forecasts. If this cannot be arranged, WWV should be monitored and information obtained from a solar observatory. If a possible outage can be forecast, then plans can be made for maximum efficiency with degraded facilities.

Recent findings in studies on digital (including teletype) error rates show that there are two general classes of errors: there is either a loss of a few bits, as might be caused by impulse noise; or a loss of many bits, caused by fading or other short term circuit failures. The former can be handled by relatively simple error detection and correction systems; however, the latter requires a repetition from the source, thus, full duplex operation is mandatory. The error detection and correction "feedback" circuit can also be used for regular traffic. Multi-bit errors are so tagged; and if the data involved is of such a nature a "repeat" is not necessary, then the "request-for-repeat" circuitry could be disabled. This would maintain higher average data rate and circuit efficiency.

3.5.5 CIRCUIT ROUTING AND SWITCHING

The general circuit routing and switching plan is as follows:

- Goldstone circuits terminate at JPL.
- Two Australian circuits terminate at JPL. During non-mission periods, one is patched through to the SFOF and one to GSFC. During mission periods both are patched through to facility responsible for the mission.
- Two South African circuits terminate at GSFC. During non-mission periods, one is patched through to JPL. During mission periods both circuits serve the responsible facility.
- At all times, JPL, which manages the DSIF's, monitors all traffic to and from the DSIF's.
- JPL and GSFC may both relay by circuit or message switching, including torn tape relay.

The above referenced circuit routing involves superfluous tandem links which add to error rates, detract from availability, and increase time of trouble location and clearance. A reduction in number of tandem links will be highly desirable upon conversion to digital data from teletype because every "circuit mile" adds to the error rate. For example, South African circuits should be routed to JPL via the most direct "electrical" route. Any monitoring by GSFC should be tapped on at the most convenient electrical point, which may not be the nearest geographical point. That is, the telemetry carrier channels should not be brought down to base band except as required by facilities of transmission medium or to regenerate the data. The GSFC tap should be at one of these necessary points, even at the expense of a few extra circuit miles.

3.6 COMMUNICATION REQUIREMENTS

The determination of communication requirements for SFOF operations was one of several vehicles utilized by the HAC communications team to orient and familiarize itself with the problems of the present and considerations of the future. Available JPL documents were studied and a series of conferences was held with representatives of the various SFOF operational areas. The intent of this phase of the task was to become better acquainted with and to document the communications aspects of the present operation, and to provide a common base for realistic extrapolation into future operations.

The final report on this particular task is attached as Appendix C. Reference to this will indicate that the accompanying discussion was concerned primarily with voice communication facilities. This emphasis was made in apparent contradiction to the fact that data and its proper distribution represents by far the primary communications load, both in terms of number of active circuits and importance of message content. The feeling was, intuitively, that the voice communications, which serve to coordinate activities and provide emergency backup, better illustrate the interrelationships fundamental to current SFOF operations.

In retrospect, it appears that this approach had as much validity as any other. Present SFOF communications are apparently a carryover from "earlier" days when the entire operation was manned by a relatively few number of experts who knew all there was to know about everything concerning the entire program. From that stage it grew into the present complex wherein a large number of "experts" insist on being provided with up-to-date information on every aspect of the operation. Such an attitude builds a magnificent esprit de corps, but it certainly complicates the communications picture.

The completion of an extensive and objective study of information exchange requirements is a necessary prerequisite to an accurate determination of communication requirements. Phase I effort included tasks to establish information exchange and communication requirements, but the time scale of activity was so short that the two tasks had to run concurrently, instead of sequentially.

Under the circumstances it appears that an accurate delineation of true information exchange, and hence communications, requirements for the SFOF will not be possible until Phase IV when the Stage I installation is fully operational and a comprehensive evaluation can be undertaken.

SECTION 4.0

COMMUNICATION SYSTEM DESIGN

4.1 INTRODUCTION

The design of the communication system for the SFOF was undertaken in two steps: an initial preliminary design, followed by a more detailed final design. The preliminary design was documented early in the Phase I effort and is attached as Appendix D. The final design grew out of the preliminary design in an evolutionary, rather than a revolutionary, manner and culminated in rough draft specifications for the various individual systems as submitted by Hughes during Phase I. Documentation of the final design appears here as a brief narrative description of those detailed specifications.

The system design is an outgrowth of JPL's present operation and represents a compromise between their current concept of an "ultimate" system and the hard realities of equipment availability, technological capability, and budgetary responsibility. Hughes' contributions to the design were limited by inadequate first-hand observation and study of actual space flight operations. Our attempt to ascertain and analyze information exchange requirements was forced by time considerations to be performed concurrently with, rather than prior to, our system design effort. As a consequence, this phase of the effort was never properly carried through to completion. Parallel study in this same area was undertaken by General Electric Co. and by the Human Factors group at JPL.

The communication system developed from this joint effort was designed to fulfill the operational requirements of present and foreseeable future deep space missions, using essentially off-the-shelf equipment. Primary information exchange is in the form of data which presently is handled predominately in teletype form. In the future, as technologically feasible, this will be converted to more efficient low speed data at equivalent teletype rates, then to high speed data transmission. Supplementary voice, teletype, and video communications facilities are utilized within the SFOF to coordinate and integrate activities and to disseminate needed information.

4.2 PRELIMINARY DESIGN

Preparation of a preliminary communication system design (see Appendix D) was undertaken at a relatively early stage of the Phase I effort for the purposes of:

- Documenting the Hughes preliminary system concepts,
- Indicating areas of inadequacies and ambiguities to be resolved before system design could be completed, and
- Providing a common base for specific constructive criticism and extrapolation into an optimum final design.

Due to our lack of familiarity with the situation and the nebulosity of the problem at that point in time, the preliminary design was necessarily vague in many respects, and lacking in the detail normally expected in a system design.

In general, the philosophy adopted then was that the communication system should be designed as the means to a more effective and more efficient space flight operation. Its purpose was to complement the efforts of intelligent, logical, and reliable users by providing necessary communications which would be adequate without being burdensome. In short, it was intended to serve as a useful tool to make the job easier for the personnel involved.

The primary system consideration is reliability. The communications system must provide a very high probability of working at full capability during specific critical times before and during a mission, and of maintaining adequate reduced capability throughout extended periods. Basic components must be carefully selected, equipment and systems must be reliably designed, and careful workmanship must be employed to ensure long service life, ease of maintenance, and simplicity and economy of repair.

The major feature of the system design is flexibility. Patching and switching access to all major system nodes will enable Technical Control to exploit to the maximum extent the full capability inherent in the installed equipment. Uncertainty in the many design areas has necessitated this flexibility in the preliminary design to facilitate accommodation of modified and completely new requirements as they evolve. This feature must be perpetuated in the final design to ensure optimum operations in emergency conditions and to permit graceful incorporation of advanced technological equipment and techniques as they become available in the future.

Major modes of communication are voice, data, and television. Operational control of these various communication systems is exercised primarily by the individual users, within the limitations and restrictions established in the centralized Technical Control area. Supervision and coordination are provided by a common communications control area.

4.3 FINAL DESIGN

The final system configuration resulted as a logical and straightforward extension of the preliminary design. System concepts remain practically unchanged, although many of the details have undergone some modification. Most of these modifications are reflected in the individual system specifications. These specifications represent the final rough drafts as submitted by Hughes to JPL. Since many of the details were in a continual state of flux throughout Phase I, the design presented here may differ in some respects from that finally delivered to the bidders. In general, these differences are small in number and in magnitude, and are of a minor nature.

The initial approach to the final design was the development of a set of specifications which would accurately delineate the functional requirements of the various communication systems. This functional approach was calculated to achieve an optimum system design by virtue of permitting potential suppliers maximum latitude to incorporate their own ideas, experience, and proprietary equipment to satisfy functional requirements. In the interest of conserving time, however, and because of other more subtle constraints, the final specifications have gone beyond the general functional concept in many respects, and have prescribed a few items which may better have been left to the discretion of the bidders. Hopefully, bidders will be permitted enough time to respond to the RFQ's so that alternative proposals incorporating fresh and independent concepts can be prepared for JPL's consideration and evaluation.

As in the preliminary design, the final design of the JPL-SFOF communications complex is comprised of the following systems: telephone, teletype, closed circuit television, paging and program distribution, and microwave multiplexer. Provisions are also included for handling a limited number of high-speed data circuits into and out of the computer. These systems are integrated functionally through a common Communications Control area, and are integrated technically through a centralized Technical Control area.

The Communications Control function supplies the coordination of activity and supervision of accessibility necessary to ensure optimum facility utilization under all operational circumstances. The Technical Control function provides the test, checkout, setup, and maintenance, both preventive and corrective, required to assure maximum equipment availability and capability.

Equipment utilized in the final communications design is off-the-shelf, either directly or with relatively minor modification. The primary system consideration is operational reliability in all its many facets: insusceptibility to failure, ease of test and maintenance, replaceability, interchangeability, etc. Of only slightly lesser importance is system flexibility to facilitate optimal system rearrangement in emergency or reduced capability modes, and to permit, without major system redesign, assimilation of advanced concepts, techniques, and technology as they become available in the future.

4.4 TELEPHONE SYSTEM

There are two modes of telephone communications required for SFOF operations. The basic requirement is for a system of conference networks for communications within the SFOF and with distant locations. Point-to-point connections and small, unexpected conferences will be cared for by a switching system.

The Conference Subsystem shall be for voice conferences which are predictable when forming operational procedures. These conferences shall each include a number of stations in the SFOF and one or two leased lines to distant locations such as a DSIF site or AMR.

The leased lines are used by JPL CENTREX for administrative purposes. During a mission, they shall be removed from the CENTREX via a capture circuit located at the CENTREX and associated with conferences in the SFOF. The controls for this capture circuit shall be located in the SFOF Communications Terminal Room.

Each conference shall either be equipped to conference a maximum number of users or a switched situation can be implemented whereby ten priority users shall have non-blocking access and up to twenty additional users can enter a conference on a random non-preferential basis. Additional non-priority users would be excluded until one of the non-priority stations leaves the conference.

The conferences will be used on a predetermined, time allocated basis; therefore, no signalling by the users is required, but equipment shall be installed to allow signalling to and from Communications Control and the distant locations.

Configurations of conferences may vary for each mission. Since the conferences vary in size from 25 to 150 conferees and there are 19 conferences, some unencumbered means (e.g., preprogrammed slip-in patchboard, simplified strapping, etc.) shall have to be utilized to minimize the time and labor involved in establishing a conference configuration.

Users shall terminate conferences on a speaker via a Speaker Conference Selector Module and/or a headset via a Headset Conference Selector Module. Both these units achieve control via selector buttons. Any button shall be able to be programmed with the capability of entering any conference.

Due to the nature of these conferences, it is not desirable to use them for communications that are not definitely of general interest. To establish point-to-point communications and small conferences, a switching system will be used.

The switching system will be basically a dial-controlled type telephone switching system performing the usual functions of interconnecting, control, alerting, attending, information receiving, information transmitting, busy testing and supervising.

Control of the switching system shall be effected with a ten digit keyboard (rather than the conventional rotary dial) and/or with preset number calling buttons which will signal the switching equipment with all the information necessary to establish a call.

Instead of the usual procedure of losing the call when the called number is busy, the equipment shall camp on the busy terminal. This then allows the calling party to be connected as soon as the called number becomes idle. The camp-on condition will make possible the design of techniques to be utilized in the case of a call of an urgent nature. A calling station shall be able to signal a busy called station that there is a call camped on the line. Certain priority calling stations shall be able to break in on a busy call.

To care for impromptu conference requirements, the Exchange Subsystem shall have conferences which can be programmed by the users.

Interconnection with the "outside world" shall be established with dial repeating tie lines to the CENTREX facilities of JPL. These tie lines shall allow incoming and outgoing connections to be established between the SFOF and JPL administrative telephones and also from the SFOF to JPL trunks for off-lab calls. The lines from the switching system which have access to the tie lines will be called Auxiliary Lines. Every user is equipped with a line for calling within the SFOF. These will be called Operations Lines.

There shall be secretarial stations which will be used to answer and screen incoming calls on Auxiliary Lines. The Auxiliary Lines shall be equipped with a holding feature to enable users to leave a line and still maintain a connection. The Operations Lines shall not be so equipped to assure that they will be idle when not in use.

The Operations Line shall be terminated on a speaker-microphone combination and the Administrative Line(s) shall be terminated on a handset. The ten digit keyboard can be associated with either type of line.

The headset can be switched to be used with a Headset Conference Selector Module, the Auxiliary Line(s), or with the Operations Line. When the headset is switched to the Operations Line, the speaker-microphone shall be disconnected.

An incoming call on an Operations Line, which is connected to the speaker-microphone, shall be connected to the speaker-microphone with no action on the part of the called party. Although the entire system utilizes push-to-talk operations, the only place where the push-to-talk operation will disconnect the mode of reception shall be when the calling party is in the speaker-microphone mode.

Contractors will be requested to recommend some means of implementing traffic studies to accurately determine quantitative requirements of future expansion.

4.5 TELETYPE SYSTEM

The SFOF Teletype System has been designed as a completely controlled and operable system within the JPL-SFOF. The system is capable of handling up to 36 separate external teletype circuits simultaneously and can distribute these circuits in a quality and quantity commensurate with the SFOF operational needs. The system provides for receiving and transmitting capability in various teletype end modes (page printers, reperforators, transmitter-distributors, and keyboards) at selected SFOF operational and technical areas and is capable of treating any one or all of the incoming circuits as sources for any one or all of the outgoing circuits.

The prime users of the SFOF Teletype System are the Computer Areas "A" and "B" which must receive data from outside the SFOF, decode and process this data, and generate data for users both inside and outside the SFOF. Data is transmitted to the Computer Areas by means of Teletype/Computer Keyers and from the Computer Areas back into the Teletype System by means of Computer/Teletype Keyers. Hence, the primary objective of the Teletype System is to provide the distribution of teletype signals to and from the Computer Areas.

The secondary users consist of several receive only user areas where all subsets are in the form of page printers or reperforators. These areas include the Space Science Analysis Areas (1 and 2), Spacecraft Performance Analysis Area, Flight Path Analysis Area, Operations Area, and Mission Control Rooms (1 and 2). These users have varying teletype capabilities according to their operational needs, and in general, possess the capability of selecting teletype circuits for their use from within a specified number of circuits. Certain of these users also possess a transmit capability, however, all teletype transmissions are individually controlled on a preprogrammed or request basis.

The remainder of the Teletype System end instrument users consist of the DSIF Control Room, the Communication Operations Room, and the following areas whose functions are related to communications operations and control:

a. Incoming Circuit Receiving and Recording Area
b. Outgoing Circuit Transmitting and Recording Area
c. Closed Circuit Television/Teletype Interface Area
d. Users Television/Teletype Interface Area
e. Communications Technical Coordinator Panel Area

Design of the System was predicated on the 36 external teletype circuits which are treated throughout the SFOF as 36 incoming circuits and 36 outgoing circuits: each external circuit was synthesized to appear internally as both an incoming and an outgoing circuit. The modules performing these synthesizing functions are capable of terminating and isolating either a half- or full-duplex teletype line.

The basic functional equipments required for the SFOF Teletype System are shown in the desired configuration in Figure 4.5-1. Further details of the system design may be found in the printed specification (HAC document number FR-62-11-104, dated 30 November 1962).

4.6 CLOSED CIRCUIT TELEVISION SYSTEM

The JPL-SFOF will utilize closed circuit TV for three distinct applications: general area surveillance, teletype data distribution, and a single, special-purpose camera overlooking the Operations Area. All cameras within the SFOF will be fixed in position, with fixed lenses, except for one special purpose camera which will have remotely controlled pan, tilt, and zoom facilities.

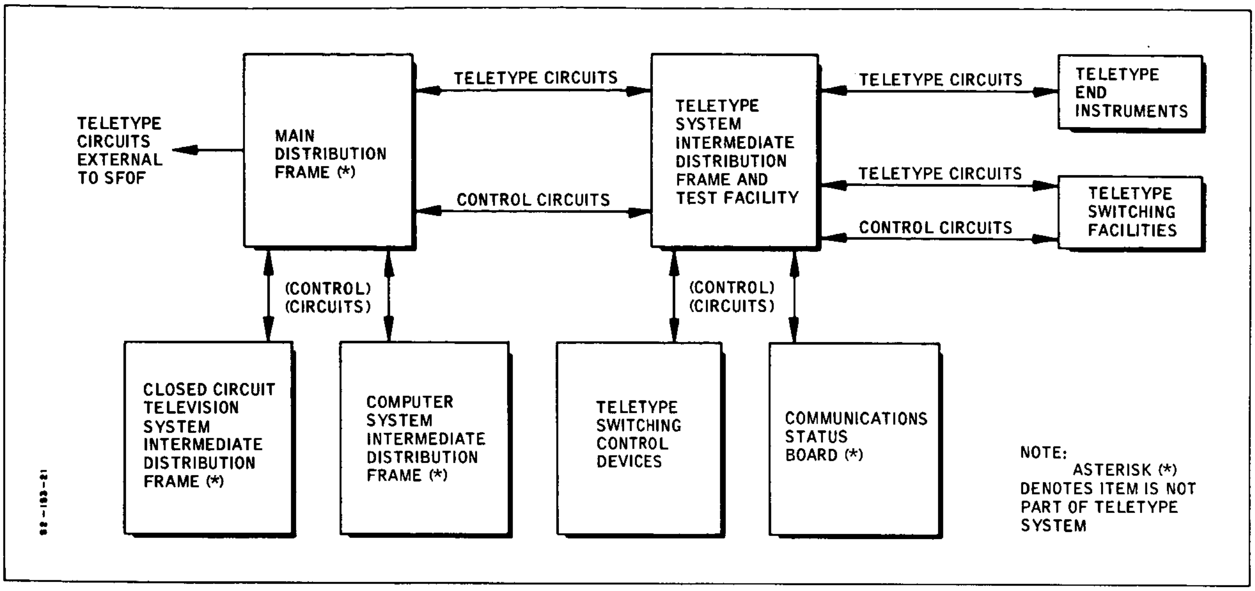

Figure 4.5-1 SFOF Teletype Functional Drawing

The system is integrated through the use of a master sync generator which supplies a coordinated sync pulse to all cameras and by means of a centralized video switching and distribution facility which permits any of the numerous TV monitors throughout the building to switch at will to the output of any camera. A broadcast TV receiver is also incorporated to permit "off-the-air" pickup of commercial telecasts as desired.

Video cables and leads for camera and switching control to locations external to the SFOF will make terminal appearances on the MDF. Similar appearances for intra-SFOF leads in these categories will be provided as required either on separate IDF's or on terminal blocks within the equipment racks.

Patching facilities required to ensure desired system reliability and flexibility will be incorporated at major system nodes. Both bridging and bidirectional access will be supplied for video circuits on either side of major system components. Plugboard or pinboard means are provided to permit control of access of the users to the switching matrix. Test and monitor facilities are provided in the Communications Terminal Room to enable centralized technical observation and control of the system and its operation.

Individual users throughout the SFOF will utilize modules consisting of individually mounted picture tube, monitor chassis, control panel, and channel selector. These modules provide the means for selecting and controlling the TV presentation at the user locations, within the limits of accessibility established by the TV Technical Control Center.

4.7 PAGING AND PROGRAM DISTRIBUTION SYSTEM

The Paging and Program Distribution System is envisioned primarily as a means for disseminating oral information throughout the SFOF, although during non-mission times it may be utilized for other purposes such as background music and TV audio distribution. A relatively large number of closely spaced speakers will provide adequate coverage at low sound levels so as to create minimum distraction during critical mission periods.

The system will include separate amplifier-speaker subsystems for each of the major functional areas within the SFOF, one for a special class of users overlapping and augmenting the above, plus a line amplifier for use in driving audio lines external to the SFOF and as required in other special applications. Signal source inputs to each amplifier-speaker combination will be selected by means of illuminated pushbuttons rack-mounted in the basement Technical Control area.

Technical Control will furnish centralized manual switching of input connections to the various amplifier-speaker subsystems under direction from the Communications Controller. Monitoring of operation, as well as any maintenance and repair required, will be localized in and administered from this area.

The Paging System will utilize its separate operational area divisions to provide semi-selective paging within the SFOF. Designated personnel will be given access to the input of the appropriate amplifier-speaker subsystem via the SFOF Operational Voice Communications System. This access will be in the form of one or more stored-number buttons which the user may depress to establish the desired connection through the voice switching system. Messages originating in this manner will be given priority by voice switching logic over input signals selected by switching in the Technical Control area.

Certain specified personnel will be given stored-number button access to all area amplifier inputs to permit SFOF-wide paging. These connections also will be established in the voice switching system with logic to interrupt all other inputs from any source whenever an important SFOF-wide announcement is to be made.

4.8 MICROWAVE MULTIPLEXER

The Microwave Multiplexer will be employed at both terminals of the Western Union type MLD-4 microwave link between JPL Pasadena and the DSIF site at Goldstone. It will provide the capability to superimpose a number of voice-bandwidth channels plus a single broadband data channel onto the microwave radio carrier.

The multiplexer will utilize an amplitude-modulated, single-sideband, suppressed carrier modulation plan, comprising the baseband signal by frequency division techniques. Line, group, and supergroup frequencies will conform to CCITT patterns. The system will accommodate initially twenty-four voice channels in the baseband spectrum between 140 and 240 Kc/sec., and a broadband data channel in the spectrum between 0.3 and 100 Kc/s. A pilot tone derived from a master oscillator will be employed to maintain synchronization throughout the system.

Each of the voice channels will have a useable bandwidth of 300 to 3450 cps. Twelve of the twenty-four voice channels will include provisions for CCITT compatible out-of-band "E" and "M" signaling against ground or battery of either polarity and at a maximum speed of 14 pps.

The broadband data channel will have a 3 db bandwidth from 0.3 to 100 Kc/sec. and will be reserved for future data handling applications.

Failure alarms and equipment redundancy are provided for all common-use system components to ensure minimum down time, and test and patching facilities are included as required to permit complete system setup, monitoring and maintenance.

4.9 TECHNICAL CONTROL

The technical control of the SFOF communications complex will be performed from the Communications Terminal Room in the basement. Such control will include test and monitor circuits and systems, preventive and corrective maintenance, administration of access of users to facilities, supervision of external circuits, and system modification to accommodate changing operational requirements occasioned by mission developments or emergency situations.

Technical Control considerations are, to a certain extent, included as a part of the individual system specifications. In some cases, jack fields and plugboard patching facilities are indicated, test equipment and monitoring provisions are included, and status displays are specified. In other cases, the bidder is requested to recommend appropriate facility control and testing and maintenance equipment and techniques. Such features will be furnished as needed by the separate suppliers insofar as is practical, plus additional facilities as required to equip a comprehensive test and control installation.

Coordination and integration of the SFOF Technical Control area will be undertaken as part of the Phase II effort. Present concepts envision approximately nine racks of patching and measuring gear. These racks will be allocated on a functional basis, by system, to provide bidirectional access on either side of every equipment of every communication system and subsystem. Test and measuring equipment will be incorporated to ensure the realization of optimum facility capability.

4.10 HUMAN FACTORS

The function of human engineering is to optimize the man-machine and man-man interface in equipment design. The major output of Phase I was functional specifications, therefore, there was a minimum of human engineering necessary. However all preliminary designs and initial draft of specifications were reviewed by human engineering personnel.

The basic function of human engineering, determination of the size, location, color, etc., of operational controls, loudspeakers, handsets, was considered in preparation of the teletype switching and operational voice system specifications. Selection of pushbutton switches for the teletype system was largely determined by available switches to perform the functions required and have a large enough push-plate to adequately display four lights. The layout and spacing was then determined in conjunction with JPL human engineering personnel. Selection of pushbuttons and their spacing, and other elements of human engineering pertaining to the voice system, is to be based on best commercial practice, as may be represented by companies proposals. However, it may be desirable to obtain modifications because most commercial communications equipment has been designed for operation by women secretaries.

Hughes human engineering personnel were asked to comment on hands-free-answering aspects of the Operational Voice System. The comments, which were as of 22 October 1962, follow:

Requirements

The Intercom is part of the SFOF Voice System. The requirements for this system were specified in a JPL document, "SFOF VOICE SYSTEM OPERATION." The Intercom will terminate on either a 2-way speaker or a headset. The particular termination is to be at the option of the user. Calls will be placed by Intercom push-button and/or Intercom dial. All Intercom stations will have the dial; but the push-buttons will be provided only where needed. Whatever the termination in use, only the calling party will be required to operate a push-to-talk switch. This action will control the direction of transmission. The purpose of this approach is to have "hands-free" operation for the called party.

Problem Situation 1

Under the hands-free requirement, the Intercom switching equipment will be under complete control of the calling party. Hence, the Intercom subsystem returns to normal only when the calling party disconnects. The requirements also imply that, when a call is placed, the push-to-talk switch of the called party will be by-passed.

A problem arises if the calling party should neglect to disconnect when through with the contact. In this event, the previously called party is effectively denied use of the Intercom. Extra effort will be required, on his part, to re-establish the system. If the latent direction of transmission is to the previous calling party, it may be possible to request a disconnect over the Intercom. Otherwise, the previously called party may have to leave his station to make a personal request. Clearly, this is an undesirable situation.

Problem Situation 2

A second operational problem may arise in the course of a conference call. A calling party establishes a conference by successively connecting to the parties desired. As before, switching for the entire conference net is under the complete control of the calling party, and the push-to-talk switches of all called parties are by-passed.

The situation is likely to arise where one of the called parties would like to contact another about some matter not pertinent to the conference. It would be desirable to have the capability for making this contact outside the conference net. This would keep the irrelevant information flow out of the net, and would act to lower the level of the general background. However, with the configuration established above, the called parties of a conference net can talk to each other only through the net itself. They are not able to make contact outside of the net. This lack will tend to increase the amount of irrelevant information flowing in the conference net, and this, of course, lowers operational efficiency.

Problem Situation 3

Another problem situation will arise in the event that a called station is unattended. As has been previously noted, with the required hands-free operation, the push-to-talk switch of the called party is by-passed by the action of the calling party. Thus, a signal light is not needed to indicate an incoming call. The incoming call is indicated by the verbal call itself.

If the called station happens to be unattended, the attempts of the calling party to establish contact may become somewhat protracted. These attempts will be verbal calls over, most likely, the loudspeaker termination of the called station. Since the stations are not acoustically isolated, this will tend to distract the adjacent stations by producing a background of irrelevant information. If the distraction is severe, or the contact critical, the adjacent station may even have to respond to the attempted contact. All this is not contributory to an efficient operation.

Recommendations

If the hands-free requirement is strictly adhered to, there are no really effective measures for alleviating the operational objections raised by the above three problems. Training the calling party to disconnect when through with his call aids in overcoming the first problem. Making sure an Intercom station is never unattended overcomes the third problem. However, such procedural precautions are never certain.

It is suggested that the called parties be given the capability for disabling the hands-free operation at their option. Since the hands-free requirement is designed primarily for the convenience of the called party, this modification does not seem unreasonable. It does not detract from the intent of the requirement. This capability might be implemented in the form of a two-position switch. A normal position would give the required hands-free operation.

A "disable" position might simply remove the short around the called party's push-to-talk switch. In the "disable" position, incoming calls would be indicated by a signal light. When the particular station is not in active use, the switch would be on "disable." If the signal indicates an incoming call, the called party would put the switch on "normal"; and operation would be as specified. Such a capability would seem to overcome the operational objections which have been raised.

Hughes human engineering personnel were also asked to comment on speaker use and location problems of the Operational Voice System. The comments, which were as of 22 October 1962, follow:

Requirements

In addition to the overhead Public Address speaker system, several speaker terminations are specifically required for each operating position. Each user will have two Monitor speakers. Each one of these may be independently switched to any one of ten leased lines. Also, this switching is independent of the leased line selected for headset use. The user will also have what might be termed a Back-up Monitor speaker. The headset is normally connected with the system of leased lines. However, the headset can be transferred to the Intercom or the commercial phone. In this case, the Back-up Monitor speaker is automatically connected to the leased line previously selected for the headset. Of course, the user position also has the two-way speaker termination for the Intercom.

These requirements for the headset and loudspeaker terminations yield three possible connection configurations. These are:

1. Normal - Headset connected to a leased line
   - A. Two-way speaker termination for the Intercom
   - B. 2 Monitor Speakers connected to leased lines
   - C. Overhead Public Address Speaker system

2. Headset connected to Commercial Phone System
   - A. Two-way Speaker termination for the Intercom
   - B. Back-up Monitor Speaker connected to leased line
   - C. 2 Monitor Speakers connected to other leased lines
   - D. Overhead Public Address Speaker System

3. Headset transferred to the Intercom
   - A. Back-up Monitor Speaker connected to leased line
   - B. 2 Monitor Speakers connected to other leased line
   - C. Overhead Public Address Speaker system

In addition to the headset, the requirements result in three to four loudspeakers directing information to a specific operation position. Also, information of a general nature is transmitted through the Public Address speaker system.

Loudspeakers as Terminations

Generally speaking, loudspeakers are a poor means of selectively presenting verbal information. They are properly used only for "broadcast" purposes, where everyone is to receive the same information. An example of this would be a Public Address system.

In all the other uses, the primary objection is their broadcasting characteristic. The operating positions within the SFOF are not acoustically separated. Loudspeakers are used to direct information to a particular position. Adjacent positions will also be able to hear this transmission; and the information is very likely to be irrelevant to their function. The amount of this "crosstalk" is increased by the number of operating positions. Distraction and confusion are obvious results. This will lead to errors in the reception of relevant information. Experimental evidence substantiates this conclusion. (Though not precisely the same situation, some of this evidence may be found in Reference 4. General substantiation may be found in Reference 1.)

Overlapping Signals

Concern here is with the isolated operating position. The headset and all loudspeaker terminations are very likely to be presenting information at the same time. This results in the problem of overlapping signals. To enable further discussion, two more terms will have to be defined. A Monitor function may be defined as that where a listener is concerned only with detecting whether or not information relevant to his task exists. Irrelevant information would be considered to be "noise." An Attention function may be defined as the case where the listener is concerned with following the content of the signal.

Since reasons were not given for the required voice system terminations, it is difficult to give a specific critique of the requirements. It is not clear what function is expected of the operator with regard to each of the terminations. From the possible configurations given by the requirements, each listening position may be required to pay attention to one source while monitoring up to five. However, when the headset is not connected to the Intercom, it may be necessary for the position to pay attention to two sources while monitoring up to four. In this absence of clear function definition, it is possible to offer only very general "human-factors" for consideration.

It has been experimentally shown that the human can devote his complete attention to only one verbal-information signal at any one time (see Reference 1 through 4). Hence, if he is presented with more than one signal, the listener must "time-share" his attention. This implies that some of the content of each one of the signals will be missed, or ignored. As the number of overlapping signals increases, the fraction of the content missed will increase. Hence, if the listening position is expected to pay attention to more than one signal, his performance with each will be degraded.

The monitor function necessarily involves some degree of attention, depending on the amount of information necessary to establish relevancy. In a sense, then, the monitor function is never pure. Nevertheless, experimental evidence seems to indicate that the operating position would be able to monitor several signals while paying attention to another one. (Some of this evidence is discussed in Reference 1.) The experiments do not establish the number of signals the listener will be able to monitor. However, it would seem that the monitoring capability is degraded when relevant information occurs at the same time in different signals. In any case, it seems reasonable to assume that the listening position will be able to monitor more than one signal.

It should be noted that the above discussion has been concerned with signals, not with the signal sources. The signal sources in this case would be the individual loudpseaker terminations. Experiments have given some indication that the number of competing signals is more significant than the number of loudspeakers (Reference 3). This would apply to the situation where the number of signals is less than the number of loudspeakers. The same experiments indicate that some arrangements of the loudspeakers tend to enhance the capability for source discrimination. And this, in turn, would seem likely to improve the listener's monitoring and attention capability.

A disturbing phenomenon has been shown to occur when a listener is presented with several overlapping signals. This is the so-called "capture" effect. First, assume that the listener is required to pay attention to all the signals presented. If one of the sources presents a significantly more infrequent signal, attention tends to be "captured" by the infrequent source. On the other hand, if the listener is expected to only monitor the infrequent source, while paying attention to the other source(s), the "capture" is in reverse. That is, the operator will tend to ignore his monitor function. This effect was demonstrated in a series of experiments by Poulton (Reference 3).

To sum up, in considering the problem of overlapping signals, there are several "human-factors" which must be included. Some of these are: (1) capability for performing simultaneous tasks; (2) monitor vs. attention capabilities; and (3) the "capture" effect.

Comments

There is a great deal of literature in Experimental Psychology which deal with the problems here. Some of the more immediately applicable literature is indicated in the References.

As is indicated by the above discussion, the optimum approach to the overlapping sources problem is to ensure that only one signal is presented at a time; or, to give the listener control over which loudspeaker is to be active. Barring this, there are still some steps to be taken. Where a number of loudspeakers must be used, experiments seem to indicate that a horizontal arrangement is to be preferred (Reference 3). The headset (the phone part) should be acoustically transparent; so that the operator may listen to the loudspeakers binaurally. It has been shown that intelligibility and the capability for source discrimination are increased when listening binaurally (Reference 5).

Not much can be done about the "broadcast" problem presented by a loudspeaker termination. The only recommendation that can be made is to acoustically separate the positions as much as possible, consistent with the other requirements of the SFOF.

Summary

Under the requirements, up to five loudspeakers may be feeding information simultaneously to an operating position. The implementation of these requirements presents no problem at all. Loudspeaker terminations present a problem because of their "broadcasting" nature. The only recommendation that could be made here was to have as much acoustical separation as possible between operating positions. The other objection was the basic problem of the overlapping signals presented by the multiple speaker terminations. The recommendation was made to limit the number of overlapping signals. To enable binaural listening at all times, it was recommended that the headphone be acoustically transparent. Also, a horizontal arrangement of loudspeakers was suggested to enhance the capability for source discrimination.

References

The listed references are certainly not exhaustive of the subjects of concern. However, they are pertinent to the problem at hand. The first two references include some bibliographies of more literature. To give some idea of their applicability, notes or quotations follow each of the references.

1) Conflict, Arousal, and Curiosity
   D. E. Berlyne
   (McGraw-Hill, 1960)

   In particular, see Chapter 3 beginning on page 45. This chapter treats the basic notion of attention and the human's capability in this direction.

2) Perception and Communication
   D. E. Broadbent
   (Pergamon Press, 1958)

   The book discusses the general subjects of hearing perception and behavior. Rather than making any definite conclusions, the attempt is to clarify the approach to the problem. Specifically, multi-channel listening is discussed from the following aspects:

   1. as affected by information presented
   2. as affected by localization
   3. as affected by spectral filtering
   4. as showing effects other than masking

Some of the more pertinent statements follow:

> "The capacity of the brain will limit the number of tasks that can be performed simultaneously; and part of the information presented must be discarded."

> "Different simultaneous speech tasks interfere with one another. This is ascribable to the limited capacity of the listener, which makes necessary some selection among the information reaching the sense organs."

> "Any novel stimulus is especially likely to be perceived; and to prevent others from evoking reaction. An intense stimulus is also more likely to be perceived."

3) <u>Listening to Overlapping Calls</u>
E. C. Poulton
(Journal Experimental Psychology, Vol. 52, 1956)

The paper presents, and discusses, the results of experiments aimed to determine the effect of two competing messages, presented simultaneously from different loudspeakers. One of the results was the "capture" effect, discussed elsewhere in this paper. Another interesting finding was the fact that the number of competing messages was more significant than the number of loudspeakers.

4) <u>Effects of Ambient Noise and Nearby Talkers on a Face-to-Face Communication Task</u>
J. C. Webster and R. G. Klampp
(Journal Acoustical Society America, July 1962)

"Communications errors defy simple description, but in general (1) for a constant noise level, increasing the number of talkers results in increasing errors; and (2) for three or fewer talker-listener pairs, percent error does not increase until the ambient noise level reaches 85 db."

The experiments discussed in this paper involved each talker reading one word at a time to his listeners, who then repeated the word back for verification.

5) <u>Some Aspects of Binaural Signal Selection</u>
E. D. Schubert and M. C. Schultz
(Journal Acoustical Society America, June 1962)

"Two experiments are reported which measure the increase in intelligibility occasioned by listening binaurally (vs. homophasically) to running speech imbedded in interfering symbols."

SECTION 5.0

SPECIFICATIONS

5.1 INTRODUCTION

When this contractual study was undertaken it was planned to produce detail specifications, complete with drawings. It was also expected these specifications would be preceded by a final design for an interim system to be operational by 31 December 1963. However, it soon became obvious that subsystems delivered by different companies would be different in price, different in technical design, and all could probably satisfy the functional requirements. Therefore, there was an evolutionary process, from preliminary design, through many conferences between Hughes and JPL personnel, to functional type specifications. Final designs, as such, were never prepared, except as this final design is represented by the specifications.

The procedure followed in preparation of the specifications was as follows:

Subsystem functions and parameters determined on basis of information exchange required, communication requirements, preliminary design, JPL documents, and conferences with JPL personnel.

These "NOTES" were then discussed within the Hughes section, which included operations research, reliability, and human factors personnel. There were then discussed with JPL personnel. (At this time JPL had a very small operations communications group).

Then initial draft specifications were prepared and officially submitted to JPL. These specifications were then reviewed by the entire Hughes project section.

Hughes and JPL engineers then jointly reviewed the initial drafts and then final draft specifications were prepared by Hughes and officially submitted to JPL.

These final drafts were then edited jointly by Hughes and JPL engineers and submitted to JPL technical publications for final editing and publication for release with requests for quotation.

Each specification did not follow this exact procedure. Subsequent paragraphs describe the preparation of each specification and give its location in the Appendices.

5.2 OPERATIONAL VOICE COMMUNICATION SYSTEM

The initial draft specification for the telephone subsystem was officially transmitted to JPL on 8 November 1962. This specification was reviewed in detail jointly by JPL and Hughes engineers. A final draft specification was then prepared and officially submitted to JPL on 20 December 1962. A copy of this design specification, "SFOF OPERATIONAL VOICE COMMUNICATIONS SYSTEM" is included in this report as Appendix E. (The initial draft is available in Hughes and JPL files under reference 62 HF-3334/9824 Contract 950261.)

5.3 TELETYPE SWITCHING SYSTEM

The teletype subsystem specification evolved from the preliminary communication system design and a long series of conferences between Hughes and JPL engineers. Therefore no initial draft, but only a final draft specification was prepared. It consists of 142 pages, including 22 figures and 11 tables. This specification was completed on 30 November 1962. A series of reviews was then held between Hughes and JPL engineers in order to up-date and edit the draft specification. The edited copy then went directly to JPL technical publications for preparation of final specification. The Hughes draft, "Initial Teletype Subsystem Specification for the Jet Propulsion Laboratory Space Flight Operations Facility" is available in Hughes and JPL files as technical publication FR 62-11-104, Contract 950261, 30 November 1962. Summary of the Teletype Switching System Specification is included with this report as Appendix F.

5.4 CLOSED CIRCUIT TELEVISION SYSTEM

The initial draft specification of the CCTV sybsystem was officially submitted to JPL on 8 November 1962. On 21 November 1962 Hughes and JPL engineers jointly reviewed the specification in detail. Reissue of the specification was delayed by priority work on the telephone and teletype systems. The final draft was officially released on 8 January 1963. A copy of this design specification, "CLOSED CIRCUIT TV SYSTEM FOR JPL SFOF" is included in this report as Appendix G.

5.5 PAGING AND PROGRAM DISTRIBUTION SYSTEM

The initial draft specifications for the paging and program distribution system were submitted to JPL on 8 November 1962. These specifications are to be revised and issued by JPL with no further action by Hughes personnel. The final procurement will be in several steps, that is speakers, cable, amplifiers, control equipment. This is so speakers and cable installation can be better integrated with building construction.

A copy of the design specification, PAGING AND PROGRAM DISTRIBUTION SUBSYSTEM is included in this report as Appendix H.

5.6 MICROWAVE MULTIPLEXERS

The initial draft specifications for the voice multiplexing equipment was prepared and officially submitted to JPL on 25 October 1962. This specification was thoroughly reviewed by JPL personnel for format and content because it was the first specification prepared by the Hughes JPL project team. The final draft was officially submitted to JPL on 3 December 1962. A copy of this detail specification "SFOF GOLDSTONE MICROWAVE MULTIPLEX" is included in this report as Appendix I. There was very little difference between the initial and final draft. The long period before revision was due to priority being given to other work.

An initial draft specification for teletype multiplexing equipment was completed on 12 November 1962. This specification was not submitted to JPL officially because of no foreseeable requirement. A copy of this detail specification, SFOF GOLDSTONE TELETYPE MULTIPLEX, is included in this report as Appendix J.

5.7 INSTALLATION SPECIFICATIONS

An initial draft of a specification for installation of electronic equipment was submitted to JPL. A copy of this specification, ELECTRIC AND ELECTRONIC EQUIPMENT AND SYSTEMS, INSTALLATION OF, GENERAL SPECIFICATION is included in this report as Appendix K.

SECTION 6.0

EVALUATION OF SUPPLIERS

6.1 INTRODUCTION

From the inception of this study potential suppliers of hardware were contacted. The purpose was two-fold: to determine the latest equipment available that could be used to satisfy JPL-SFOF requirements; and to brief the suppliers on problems to which JPL and Hughes were seeking solutions.

Contacts were made in coordination with Hughes Fullerton Purchasing Department. All suppliers were informed Hughes: was not buying; could not commit JPL; budgetary planning prices would not be binding; and that JPL reserved full right to solicit all suppliers in the open market.

6.2 SUPPLIER EQUIPPED FACILITIES VISITED

Limited travel funds and lack of time precluded extensive visits to military and other facilities using equipment similar to that suppliers would offer for use at JPL. Hughes engineers assigned this task were familiar with many command-control and commercial communications systems therefore extensive traveling was not necessary. Three trips were made. One to Vandenberg AFB on 22 May 1962, to see the application of ITT-Kellogg equipment; one trip to the AF Ballistic Missile Division in Inglewood, Calif., on 25 July 1962, to see the application of Western Electric equipment; and one to the Army Electronic Proving Ground (Fort Huachuca) on 20 July 1962, to study Kellogg and Stromberg solid state telephone switching equipment.

6.3 ITT-KELLOGG AT VANDENBERG

The operational systems at each complex originally contained fifty nets. These have been reduced to 21 nets, seven nets apiece for each of three launch pads with each net serving one particular phase of the operation. Such operational phases include Fueling, Telemeter Checkout, Assembly, and Stabilization Checkout. The Test Coordinator and some of his staff have their consoles in the block house configured to provide entry into any one of the nets. Provision is also made at selected console positions for having the operator's microphone and one of his ear phones on a single net while he monitors another net thru his other ear phone. This provides necessary cross-coordination between activities in a manner assuring effective operations.

All operational communications are four-wire circuits. The end-instruments can be of any desired configuration, i.e., microphone and loudspeaker, standard telephone headset, handset, or other device. The specific end instrument used for a given position is determined by requirements of that position.

For setting up nets Kellogg uses a program patch board similar to that used on IBM computers. All local line positions in a given launch complex appear at the program patch board terminals. To institute a given conference, a patch board is made up in the proper configuration and inserted in the patch board holder. In this way merely by "pulling out." one board and "plugging in" another, conference setups can be changed in a matter of seconds. This is a variation of the present "Conferencing by IBM Card" method available on Kellogg crossbar consoles. An extension of this capability will be available shortly. It will program conferences by use of the IBM card method but the card selection (and therefore conference selection) will be made by push buttons.

All of the switching of operational four-wire circuits is crossbar. However, all amplifiers, oscillators and other active circuit elements are solid state. Solid-state space-division switching is available at this time; it was not available when the communication system was installed at Vandenberg. A net consists of three to fifteen telephone end instruments on a four-wire party-line circuit. Any talker is heard by all parties to the net.

No intercom or other loud speakers are used in the block houses; all communications in these areas is accomplished by use of headphones. Such an arrangement is almost mandatory because of the densely packed work space.

Kellogg is purchasing a new type headset manufactured by Plantronics Inc., 111 Josephone Street, Santa Cruz, California. It has a small case held to the side of the head by a headband from which project two sound tubes. One tube terminates in an earpiece, the other in an open end alongside the wearer's mouth. Microphone and receiver solid-state transducers are contained in the case. This unit has been tested in high noise level locations and has given fantastic results. Intelligibility has been maintained in ambient sound levels up to 100 db. Several airlines have contracted to purchase this headset-microphone unit.

Experiments by Kellogg on use of loud speakers in noisy locations has yielded empirical statistics which indicate that the attention of a called party will normally be obtained if the loud-speaker level is at least 12 db above ambient noise. However, if the called party is alert and awaiting a call, a level of only 9 db above ambient is sufficient.

Kellogg personnel on the base vary between 300 and 500 people. This does not include sub-contractors doing such jobs as cable burial, cable terminal installation, pole line erection, and similar functions. Kellogg is negotiating to buy a contracting company in this field to put those phases of the work "in-house".

One of the lessons Kellogg has learned at Vandenberg is the value of extremely detailed plant records. Detailed records are obviously necessary for rapid troubleshooting. In addition they have found that if records are kept in unusual detail, preventive maintenance is improved almost in direct ratio to the fineness of the record.

6.4 WESTERN ELECTRIC AT BALLISTIC MISSILE DIVISION

It is the purpose of this installation to provide AF and associated VIP's with real time data on current AF ballistic missile and space operations. This includes strictly AF shoots at Vandenberg and Cape Canaveral, as well as AF launching of NASA flights. On these latter, AF responsibility officially ceases at injection, but continuing or additional information can be requested from NASA as local interest dictates. Present facilities permit the monitoring of two operations simultaneously. This monitoring is not an active participation in data analysis and vehicle control such as is carried on by the JPL-SFOF. Rather it is a passive reception and display of information pertinent to significant events as they happen.

The installation consists of two adjacent rooms: a Display room, and a Communications room. The Display room seats 18 or 20 people in upholstered chairs facing the common wall between the two rooms. This wall contains clocks, a status board, a map of the world for plotting missile and space tracks, and several translucent panels for rear-projection of various forms of graphic information. All plotting and support information is entered and modified from the Communications side of the wall by means of grease pencils, Telecon and Vu-Graph projection systems, and, where possible, by pre-prepared cards to record standard events. These cards are painted with fluorescent paint and appear in "windows" on the status board. "Black light" illumination on the front of the board creates a spectacular display.

The Communications room contains a two-station console from which all lights, count-down clocks, and communications facilities in both rooms are controlled. Voice and teletype lines are available to AF installations all over the world. Operational control of these and local telephone circuits is exercised by means of what is essentially a super Bell Telephone Call-Director operating as a cordless switchboard. Calls and conferences are set up as required by the operators via push-buttons and dialing.

Operations at this installation are similar to but considerably less complex than those of the SFOF, since no data reduction is involved.

6.5 KELLOGG AND STROMBERG AT FORT HUACHUCA

Equipments under test have been of two manufacturers, Stromberg and Kellogg. Stromberg is time-division; Kellogg is space-division switching. The following items apply to both equipments.

Solid State switching produces higher reliability than crossbar in widely varying ambient conditions of temperature and humidty.

Cost, at the present time, is about the same as crossbar.

Tones are used for supervisory and switching functions. This permits many more functions and refinements than pulse dialing. Identical tones are used in the Kellogg and Stromberg exchanges.

Both equipments as originally delivered had numerous minor "design bugs". These were "shaken down" during the test. However, this is a point to carry in mind when considering purchase of any equipment that ~~not~~ had such a shakedown.

Examples:

Flexible cables in pull-out drawers that got into the guide slots and were crushed causing cross-connections grounds, and shorts that damaged components.

Intermittent occasional break in the dialing sequence caused an element of confusion in repreat-back of dialing numbers between two exchanges (required an additional relay).

"Ring-back" from one phone receiving a busy signal disconnected all "Camp On's" connected to a busy-back bus (corrected by changing signal levels.)

Operating over a noisy circuit noise pulses interferred with the tone signals and gave wrong numbers, disconnect, or no result at all. (Corrected by changing tolerances on acceptable tone levels). Results of the above correction permitted dialing correctly over a noisy tropo circuit that was so bad that intelligible speech could not be trasmitted.

The above examples are some of the many that appeared during the shakedown of both equipments. However, as of now, test personnel believe that either Kellogg or Stromberg equipments are of superior quality and reliability compared with conventional crossbar, panel, or step-by-step.

Quality of transmission of either equipment was excellent. Limitations due to distortion, band width or phase delay are less than the best of multiplexing equipment used in the tests.

No tests were made using data transmission thru the exchanges. However, where a single voice channel is concerned, performance should be equivalent to a "metallic circuit".

Where double or triple voice channel bandwidth is required, the Kellogg equipment should give performance equivalent to a metallic circuit whereas the Stromberg time-division equipment would require use of two or three channels properly placed in the sampling sequence to double or triple the single-channel sampling.

Test personnel think there is an economical crossover above which time division should be more economical than the space division matrix. This may occur as low as 35 lines.

Above the critical number of lines requires more than one matrix with inter-matrix trunking and signaling. There is more to be said in this regard as the cross over to multiple matrices may not be the same as the economic cross over. Furthermore with recent reduction of the final relay to a transistor and reduction in cost of transistors, the cross over point may be at a much higher number of lines.

6.6 COMPANY REPRESENTATIVES VISITING HUGHES FULLERTON

Company representatives visiting Hughes Fullerton were briefed on entire JPL-SFOF communication system requirements or on particular subsystems, depending on their interest. It is interesting to note that Pacific Telephone and Telegraph had fourteen representatives at a briefing on 24 October 1962, including two men from San Francisco.

6.7 EVALUATION OF PROSPECTIVE BIDDERS

One of the Phase I objectives of the HAC Communications Study effort was an evaluation of the equipment manufactured and the capability of potential bidders for the various subsystems comprising the SFOF Communications complex. This evaluation was to result in the recommendation of at least three suppliers who in HAC's judgement have the ability to fabricate, deliver, and install the needed equipment in a satisfactory manner.

During the development and evolution of the subsystem design concepts, a number of discussions were held with representatives of a variety of possible suppliers, and a substantial amount of sales and technical literature was reviewed in each area. In a relatively few instances, it was possible to observe actual equipment demonstrations and installations representative of SFOF applications. In general, however, contact was entirely oral with a small number of sales and/or technical personnel.

Under the circumstances of such contact and the comparatively short time available for it, a complete evaluation of potential bidders is obviously difficult and inconclusive. Technical competence was in most cases not directly demonstrable (except possibly by reputation), and in only a very few cases was it possible to observe representative installations. In no case was either corporate management evaluated or financial responsibility determined.

The attached listing, therefore, merely documents the vendors contacted in HAC's study effort in the areas of telephone, teletype, microwave multiplex, closed circuit TV, and public address systems. The list for each of these categories is, where applicable, further divided into the following groups in accordance with HAC's experience with the particular vendors:

I. High interest in problem; very cooperative in supplying information and helpful suggestions.

II. Normal interest and response.

III. Little or no apparent interest; minimum or no response.

IV. Equipment not applicable to present requirements.

On the basis of the information now at hand, there is no reason to exclude any of those in groups I, II, or III from an approved bidders list. On the other hand, however, the appearance of a supplier's name on these lists should in no way be construed as an endorsement by Hughes Aircraft Company, nor should it be implied as a conclusive indication of individual capability.

Several of the suppliers expressed interest in submitting a combined bid on all communications systems for the SFOF. These are denoted by * in the attached listings. In addition to those contacted, there are a number of diversified electronics organizations in Southern California with general capability in one or more of the pertinent areas. These include, among others:

Aeroneutronics	Interstate Electronics
Autonetics	Lear-Siegler
Beckman Instruments	Litton Industries
Consolidated Electrodynamics	Packard Bell Computer
General Dynamics/Electronics	Nortronics
Hughes Aircraft	Thompson Ramo Wooldridge

which probably should be given the opportunity to bid all or portions of this job.

<u>CLOSED CIRCUIT TV</u>

I. American Microwave and TV Corp., Vicon Division
Brown Engineering
Cohu Electronics, Kintel Division
General Electric
General Precision, Inc., GPL Division
Motorola
Thompson Ramo Wooldridge, Inc., Dage Division

II. Blonder-Tongue Laboratories
Diamond Electronics
EMI/US
ITT, Industrial Products Division
Maryland Telecommunications, Inc.
Packard Bell Electronics
RCA
Sarkes-Tarzian, Inc.
Sylvania Electric Products

III. Community Engineering Corp.
Hallamore Electronics
ITA Electronics
Itek Corp.

IV. Bell Aerosystems Co.
Philco Corp.
Raytheon Co.
Telemet Corp.

PUBLIC ADDRESS

I. California Sound Products
Douglas Roesch Communications

II. Hannon Engineering
Kierulff Sound
Langevin Co.
Meredith Engineering Assoc.
Midwest Audio Corp.
RCA
Telefunken

TELEPHONE

I. Automatic Electric*
Bell Telephone System*
ITT Kellogg*

II. North Electric Co.*

III. General Dynamics, Telecommunications Division (Stromberg Carlson)
North American Phillips Co.

TELETYPE

I. Automatic Electric*
Bell Telephone System*
GPI (Librascope)*
ITT Kellogg*
Milgo Electronics
North Electric*
Radiation, Inc.
Robertshaw Fulton
Tridea Electronics*

MICROWAVE MULTIPLEX

I. Lenkurt Electric
   Motorola Communications and Electronic, Inc.

II. General Electric, Comm. Products Dept.

JPL-SFOF COMMUNICATIONS STUDY - PHASE I FINAL REPORT

APPENDIX A, PART I

STATEMENT OF WORK AND TASKS

INTRODUCTION

This appendix includes Phase I details of the following:

The first item received by Hughes was the Statement of Work (see Part 5), less paragraph C, Human Factors. From this, and the rest of request for proposal issued by JPL, the Proposed Study Plan (see Part 2) was prepared. Before this study contract became effective, JPL requested addition of paragraph C, to the Statement of Work. Hughes response was the Supplement to the Proposed Study Plan. This then resulted in the final contractual Statement of Work.

Before the first working meeting with JPL personnel, Hughes prepared a Preliminary Work Plan (see Part 4).

JPL and Hughes engineers mutually arrived at a set of Major Tasks to be performed in order to properly comply with the Statement of Work (see Part 6). Actual execution of these tasks by Hughes required a further breakdown into Detailed Subtasks (see Part 7).

The relationship of the Detailed Subtasks to the Major Tasks and Statement of Work is shown in Part 8.

Two items: 3. Produce Operational Communications Handbook; and 9. SFOF Design Book Functional Specifications; shown in Part 6, were not performed because they were over and above the proposed work and could not be performed with engineering time available on the contract.

PHASE I - PROPOSED STUDY PLAN

INITIAL COMMUNICATIONS DESIGN

The primary objective of the SFOF is to provide a centralized capability to conduct space flight operations in support of a wide variety of lunar, planetary, and interplanetary exploration programs for the NASA. Successful accomplishment of this objective depends directly upon the success of the communications system in integrating sensors, data handling and processing services, and control functions into an effective and efficient operational and functional system. Maximum effectiveness of the ultimate facility complex will not result from chance. Its foundations must be based on intelligent early system planning and engineering, and its potentialities will be achieved by operational perspicacity and diligence.

The development of an initial communications design for the SFOF installation at JPL will be undertaken as a projection of the preliminary design and technical decisions presented by JPL in Engineering Planning Document No. 68. This document will provide part of the basis for an engineering and evaluation study of the fundamental purposes and objectives of the SFOF, the nature of its mission in the expanding space effort, and its probable future role in man's extension of the space frontier. With this background, the proposed communications study will encompass the:

- Evaluation of communications requirements
- Evaluation and revised design of the initial system
- Development of system specifications

The final report for Phase I will summarize the findings of this initial work and will serve as the foundation upon which subsequent phases will build toward the ultimate system.

EVALUATION OF COMMUNICATIONS REQUIREMENTS

The first step toward sound system design is an accurate determination of the system objectives and the requirements which prescribe its composition and operation. JPL document EPD-68 presents current preliminary design concepts and represents an initial source of general information on the SFOF. Further detailed information will be sought from:

- Additional JPL documentation of planning
- Discussions with JPL management and operating personnel
- Existing JPL and NASA operating procedures

- Non-JPL project personnel
- Discovered sources not presently known

Further enlightenment on planned communication system requirements and operational procedures will be generated by the displays and systems task teams working concurrently with the communications team. The necessity for allocating adequate and appropriate intrafacility communications provides a valuable and effective coordinating influence on the development of complex systems of this type.

All available information will be studied, evaluated, and organized into an integrated and consistent set of practicable requirements for SFOF communications.

DESIGN OF INITIAL SYSTEM

With communication requirements tentatively established, the system needed to satisfy those requirements can be developed. SFOF communications facilities will employ telephone, teletype, and data channels over wire and radio circuits. The first draft of such a system, however, must be synchronized with an investigation of the state-of-the-art hardware available for implementing the system. Even such apparently standard equipments as telephone exchanges and teletypewriters require modifications for special system requirements. Some problems arise in this area that are amenable to multiple solutions, while others are sufficiently difficult to justify a consideration of a basic change in system design.

Some examples of the factors to be weighed are:

- Two-wire vs four-wire telephone circuits
- Sophisticated narrow-band data modems vs simpler equipment requiring wider bandwidth
- Gaining the most in teletype switching by making maximum use of the capabilities of the "stunt" box (auxiliary switching control)
- Provision for future needs in telephone conferencing
- Possibility of future needs in high-speed data links for computer-to-computer information exchange
- Assurance of vital operational circuits with planned redundancy, fallback, or other means.

The list can obviously be expanded, but the listed examples illustrate the field.

Consideration of the preceding factors is further compounded by the necessity for satisfying simultaneously the operational requirements of the SFOF, the DSIF's, NASA headquarters, and other possible participating facilities. All these various operations must be compatible with and effectively coordinated into the final system design.

At this point in the study, system design, operational requirements, and hardware planning will be co-mingled with cost, availability, and reliability considerations. Hardware that does not justify its cost, either in satisfaction of requirements or in system performance, should be reconsidered. System design complexity or sophistication that endangers reliability, or contributes to difficulties in operation or maintenance, or is excessive in cost, may justify a relaxation of certain requirements. Conversely, re-examination of the system in the light of obtainable performance or increased overall flexibility may warrant more stringent requirements in some areas.

DEVELOPMENT OF SYSTEM SPECIFICATIONS

Completion of the preliminary system design will permit equipment specifications to be prepared. The writing of these specifications will afford the opportunity to re-evaluate the implementation problems and include required changes in system design or operational requirements. When such flexible constraints become firm, three competent potential contractors will be named for inclusion on the bidding list.

PHASE I FINAL REPORT

Although Phase I of the study will evolve a preliminary system design and a set of specifications as its principal result, documentation of the methods used is of importance.

Many questions will be asked concerning apparently arbitrary choices of system configuration or hardware. Documentation of the process whereby these choices were made is insurance against future ill-chosen modifications based on lack of that knowledge.

Hughes Ground Systems has a staff of experienced engineering writers, artists, and other publication specialists. They are well qualified in preparation of handbooks and other technical documents, and will be made available for assuring the quality of both the specifications and the Phase I final report.

APPENDIX A, PART 3

PHASE I - PROPOSED SUPPLEMENT TO STUDY PLAN

(Addition of Human Factors)

GENERAL

The desirability and importance of adequate consideration of the Human Factors aspects of the communications subsystem throughout the critical Phase I evaluation study and design period have been mutually recognized by JPL and Hughes Aircraft Company. This supplementary proposal recommends strengthening this facet of the Phase I effort to the extent of adding the equivalent of one man full time to this field. Such work will be divided as necessary into two distinct but closely allied areas:

1. System Engineering - The study of the human being and his interrelationship with the communications subsystem and with the other individuals contributing to its operation, and

2. Human Engineering - The development of the most effective functional coordination between the man and the equipment at his disposal.

The objective of this activity is the early recognition of and appreciation for the human problem areas arising from such an extensive complex of men and equipment, and the establishment of an intelligent approach to the optimization of their combination.

SYSTEM ENGINEERING

The design of the communications subsystem is intimately related to and interdependent with the over-all design and function of the Space Flight Operations Facility. As a consequence, communication systems considerations will be studied in close cooperation with the system design team. Systems and human engineering specialists will monitor the developing communications subsystem design and evaluate it in terms of the evolving over-all system design. Specific areas for attention include:

- Over-all information requirements
- Information flow
- Necessary decision making
  - Consideration of automatic vs human decision making
- Human information requirements
  - Aural
  - Visual
- Automatic assistance to human tasks
- Man-man and man-machine requirements

HUMAN ENGINEERING

The prerequisites for the meaningful application of the techniques of Human Engineering, per se, include at least a preliminary crystallization of over-all system and subsystem design concepts and a reasonably accurate delineation of the man-equipment interfaces. As the work for Phase I begins to finalize, efforts will be directed toward the initial development of human engineering requirements. This activity will be undertaken in coordination with the displays design team to ensure maximum functional effectiveness at each operator position. It will define human factors requirements to be included in equipment specifications and will serve as a reliable foundation for the more detailed human engineering work that must follow in the remaining phases of the program.

PHASE I - PRELIMINARY WORK PLAN

(prepared before contract became effective)

TASK	SUBTASK	DESCRIPTION
1.		Management and Continuous Coordination
	A.	Monitor all tasks
	B.	Report to superiors
	C.	Report to customer
2.		Technical Planning
	D.	Revise preliminary work plan, all tasks
	E.	PERT
	F.	GANTT
	G.	Travel
	H.	Formats: Trip, Conference, Telephone
	I.	Formats: JPL Report, Drawings, Specifications, etc.
	J.	Phase II, III, IV
3.		Consultation
	A.	World Wide Aspects
	B.	Deep Space
	C.	Wire Transmission
	D.	Radio Transmission
	E.	Digital Switching, etc.
	F.	Human Factors
	G.	A and E
	H.	Operations Research
4.		Determination of Communications Requirements
	A.	Documents to study
	B.	Conferences
	C.	Facility Visits
	D.	Consultants
	E.	Determine Communications Hierarchy
	F.	Make Traffic Analysis
	G.	Subset Requirements
	H.	Inside Plant
	I.	Outside Plant
	J.	Tabulate Problem Areas Expected
	K.	Report
5.		Study and Evaluation of Present Communications
	A.	Documents to study
	B.	Conferences
	C.	Facility Visits
	D.	JPL Terminal
	E.	Goldstone

TASK	SUBTASK	DESCRIPTION
5. (contd.)		
	F.	Other terminals
	G.	Transmission facilities
	H.	Enroute Relays and Switching
	I.	Tabulate Problem Areas
	J.	Report
6.		Study Future Communications Concepts, Relationships
	A.	NASA
	B.	DCA
	C.	UNICOM
	D.	AIRCOM
	E.	GSA
	F.	ATT
	G.	ITT
	H.	WU
	I.	Document Study
	J.	Consultant Opinions
	K.	Report
7.		Preliminary Design
	A.	System
	B.	Subsystem A
	C.	Subsystem B
	D.	Subsystem C
	E.	Subsystem . . .
	F.	Equipment A
	G.	Equipment B
	H.	Equipment C
	I.	Equipment . . .
	J.	Draft Report
	K.	Consultants Comments World Wide
	L.	Deep Space
	M.	Wire
	N.	Digital
	O.	Operations Research
	P.	Human Factors
	Q.	A and E
	R.	Reliability
	S.	Final Report
8.		Study and Evaluation of Hardware Available and Potential Suppliers, Installers
	A.	Letters to Prospects
	B.	Visit Facilities
	C.	Receive Marketeers
	D.	Preliminary Report
	E.	Consultants Remarks
	F.	Final Report

TASK	SUBTASK	DESCRIPTION
9.		<u>Reliability</u>
	A.	Inside Plant
	B.	Outside Plant: Terminal A, B, Medium, R, SW
	C.	Ionospheric Propagation (p/o B)
	D.	MTBF
	E.	In Service
	F.	Future Time Prediction
10.		<u>Final Design</u>
	A.	System
	B.	Subsystem A
	C.	Subsystem B
	D.	Subsystem C
	E.	Subsystem . . .
	F.	Equipment A
	G.	Equipment B
	H.	Equipment C
	I.	Equipment . . .
	J.	Specify Transmission Facilities Required
	K.	Specify Terminal "B" Requirements
	L.	Obtain Consultants Opinions
	M.	Report
11.		<u>Prepare Specifications</u>
	A.	Determine Format
	B.	Advance Information to A and E
	C.	Outlines
	D.	Draft
	E.	Consultants Check
	F.	Final Draft
	G.	Final Report
12.		<u>Prepare Drawings</u>
	A.	Determine Format
	B.	Drafts
	C.	Check Finals
	D.	Consultants Check
	E.	Sign Off
13.		<u>Final Report</u>
	A.	First Preliminary Outline
	B.	Assign Sections
	C.	Solicit Comments
	D.	Final Outline
	E.	First Draft
	F.	Consultants Opinions
	G.	Final Draft
	H.	Print

APPENDIX A, PART 5

PHASE I - STATEMENT OF WORK

A. Perform an engineering and evaluation study of JPL's SFOF Communication System preliminary designs and technical decisions to recommend applicable revisions and shall ascertain if any additional requirements are necessary;

B. Develop the over-all initial Communication System design and provide flow diagrams and layout drawings;

C. Conduct a human factors evaluation of the initial Communication System design, utilizing three dimensional models as required;

D. Develop the over-all initial Communication System specifications required for: (1) the implementation of the Communication System and, (2) the preparation of the Request for Proposal for an operating Communication System;

E. Recommend a minimum of three (3) sources capable of designing, fabricating and testing the equipment required to meet the SFOF Communication System specifications;

F. Prepare and submit a Final Report which shall include, but not be necessarily limited to, detailed design specifications, functional diagrams and dimensional layout drawings.

APPENDIX A, PART 6

PHASE I - MAJOR TASKS

(Derived from Statement of Work)

1. Management and Coordination
2. Evaluate Existing System
3. Produce Operational Communications Handbook
4. Determine User Requirements
5. Evaluate JPL Conceptual Design
6. Preliminary Design
7. Preliminary Design Review by JPL
8. Evaluate Available Hardware and Contractors
9. SFOF Design Book Functional Specifications
10. Final Design
11. Final Design Review by JPL
12. Specifications and Drawings
13. Final Report

JPL-SFOF COMMUNICATIONS STUDY - PHASE I FINAL REPORT

APPENDIX A, PART 7

PHASE I - DETAILED SUBTASKS
(as performed by project engineers)

a. Management
b. Determination of Information Exchange Requirements
c. Determination of Communication Requirements
d. Evaluate Present System (JPL Terminal)
e. Evaluate Overseas Transmission Media
f. Evaluate JPL EPD-68 Preliminary Design
g. Product JPL Operational Communications Handbook
h. Examine and Report on Reliability Factors
i. Examine and Report on Operations Analysis Human Engineering Factors
j. Study Future Concepts
k. Produce Preliminary Design
l. Consultant Review Preliminary Design
m. JPL Review Preliminary Design
n. Study and Evaluate Available Hardware
o. Evaluate Prospective Contractors
p. Produce Final Design
q. Produce Functional Specifications for JPL SFOF Design HB
r. Consultant Review Final Design
s. JPL Review Final Design
t. Produce Drawings and Specifications
u. Final Report
v. Monthly Technical Reports
w. Monthly Technical Meetings
x. Oral Report

PHASE I – RELATIONSHIP OF DETAILED WORK PLAN TO THE CONTRACTUAL STATEMENT OF WORK

STATEMENT OF WORK ITEM	MAJOR TASK	DETAILED SUBTASK	DESCRIPTION
A.			Perform an engineering and evaluation study of JPL's SFOF communication system preliminary designs and technical decisions to recommend applicable revisions and shall ascertain if any additional requirements are necessary.
	2.		Evaluate existing system
		d.	Evaluate present system (JPL terminal)
		e.	Evaluate overseas transmission media
	3.		Produce operational communication handbook
		g.	Produce JPL operational communication handbook
	4.		Determine user requirements
		b.	Determine information exchange requirements
		c.	Determine communication requirements
	5.		Evaluate JPL conceptual design
		f.	Evaluate JPL EPD-68 (Preliminary design)
		j.	Study future concepts
B.			Develop the overall initial communication system design and provide flow diagrams and layout drawings.
	6.		Preliminary design
		k.	Produce preliminary design
		l.	Consultant review preliminary design

STATEMENT OF WORK ITEM	MAJOR TASK	DETAILED SUBTASK	DESCRIPTION
	7.		Preliminary design review by JPL
		m.	JPL review preliminary design
	9.		SFOF design book - communication section
		q.	Produce functional specification for JPL SFOF design handbook
	10.		Final design
		h.	Examine and report on reliability factors
		p.	Produce final design
		r.	Consultants review final design
	11.		Final design review by JPL
		s.	JPL review final design
C.			Conduct a human factors evaluation of the initial communication system design, utilizing three dimensional models as required.
		i.	Examine and report on human factors
D.			Develop the over-all initial communication system specifications required for: (1) the implementation of the communication system and; (2) the preparation of the request for proposal for an operating communication system.
	12.		Prepare specifications and drawings
		t.	Produce drawings and specifications
E.			Recommend a minimum of three sources capable of designing, fabricating, and testing the equipment required to meet the SFOF communication system specifications.
	8.		Evaluate available hardware and contractors
		n.	Study and evaluate available hardware
		o.	Evaluate prospective contractors

STATEMENT OF WORK ITEM	MAJOR TASK	DETAILED SUBTASK	DESCRIPTION
F.			Prepare and submit a final report which shall include, but not be necessarily limited to, detailed design specifications, functional diagrams and dimensional layout drawings.
	13.		Prepare final report
		u.	Prepare final report

JPL-SFOF COMMUNICATIONS STUDY-PHASE I FINAL REPORT

APPENDIX B

INFORMATION EXCHANGE REQUIREMENTS

PART I. INTRODUCTION

This appendix includes operations research reports produced in order to gain knowledge and an understanding of the organization, mission, functions, and information exchange requirements of the JPL SFOF. This includes the internal operations center of the SFOF, and the important aspects and relationships of the SFOF to all external elements.

The work was performed primarily for internal Hughes use by Hughes engineers who were to design the SFOF communication system. Original reports which explained flow charts used phraseology based on principles of line-and-staff and therefore considered the test director as a MANAGER who delegated authority to subordinate units. This has been corrected to reflect the great coordination responsibility, in lieu of the "command" responsibility of the test director.

The second two parts of this appendix are reports of analysis of JPL-SFOF internal communications hierarchy and external (related) communications hierarchy. Part 3 is a report based on qualitative analysis of information exchange requirements.

Part 5 is a draft of a plan for a detailed quantitative analysis and report. Work in this area was discontinued because sufficient information had been obtained for a preliminary system design. The approach to the qualitative requirements was primarily a matrix, the nodes of which refer to a card that gives all traffic and message format characteristics. Such a solution is amenable to automation. During Phase III or IV of this study program this approach should be reconsidered as a fool-proof traffic analysis and prediction system.

JPL-SFOF COMMUNICATIONS STUDY-PHASE I FINAL REPORT

APPENDIX B, PART 2

EXTERNAL COMMUNICATIONS HIERARCHY
(As of 25 May 1962)

1.0 GROSS COMMUNICATIONS (Refer to Figure B-2-1)

1.1 Handover Coordination between the Test Director, the JPL Operations Center at AMR, and the AMR launch complex may periodically require direct voice links. AMR has control of the spacecraft until it is in parking orbit. After this has been achieved, control responsibility transfers to the Test Director.

1.2 Spacecraft Acquisition and injection conditions data is computed at AMR and sent to the SFOF Computer Center just after injection into the parking orbit. The central computing facility also begins orbital computation.

1.3 Mission Coordination between the Test Director, JPL technical management, and NASA agencies may be minimal during standard operations. During non-standard operations, however, modifications to mission objectives may be necessary and the views of related NASA agencies solicited.

1.4 News releases are approved by the Test Director and JPL management. These are typically teletyped, but telephone or face-toface interviews with the Test Director are possible.

1.5 Routine decisions concerning utilization, operation, and maintenance of SFOF communications are the responsibility of the communication director. Information required includes current mission status and detailed objectives and predictions of probable system responses.

1.6 Decisions concerning the scientific experiments being conducted with spacecraft, and the authority to originate payload commands are the responsibility of the scientific director. This will require current knowledge of mission status and the activities of the other technical areas on the part of the former.

1.7 Responsibility for decisions concerned with what and when to interrogate the spacecraft about its operating conditon rests in the Spacecraft Performance Analysis Area. This will require that the area be kept current on mission status, objectives, and ground system status.

1.8 Responsibility for decisions concerned with what special tracking and telemetry data requests to make of the DSIF's and when, rests in the Flight Path Analysis Area. These decisions will be based on present flight path data, current mission objectives, known inadequancies in flight path information, and present spacecraft condition.

1.9 Responsibility for Routine or nonstandard control of the DSIFs rests in the DSIF Control Area. This will require that DSIF Control maintain current knowledge of the status of the total system and its immediate objectives.

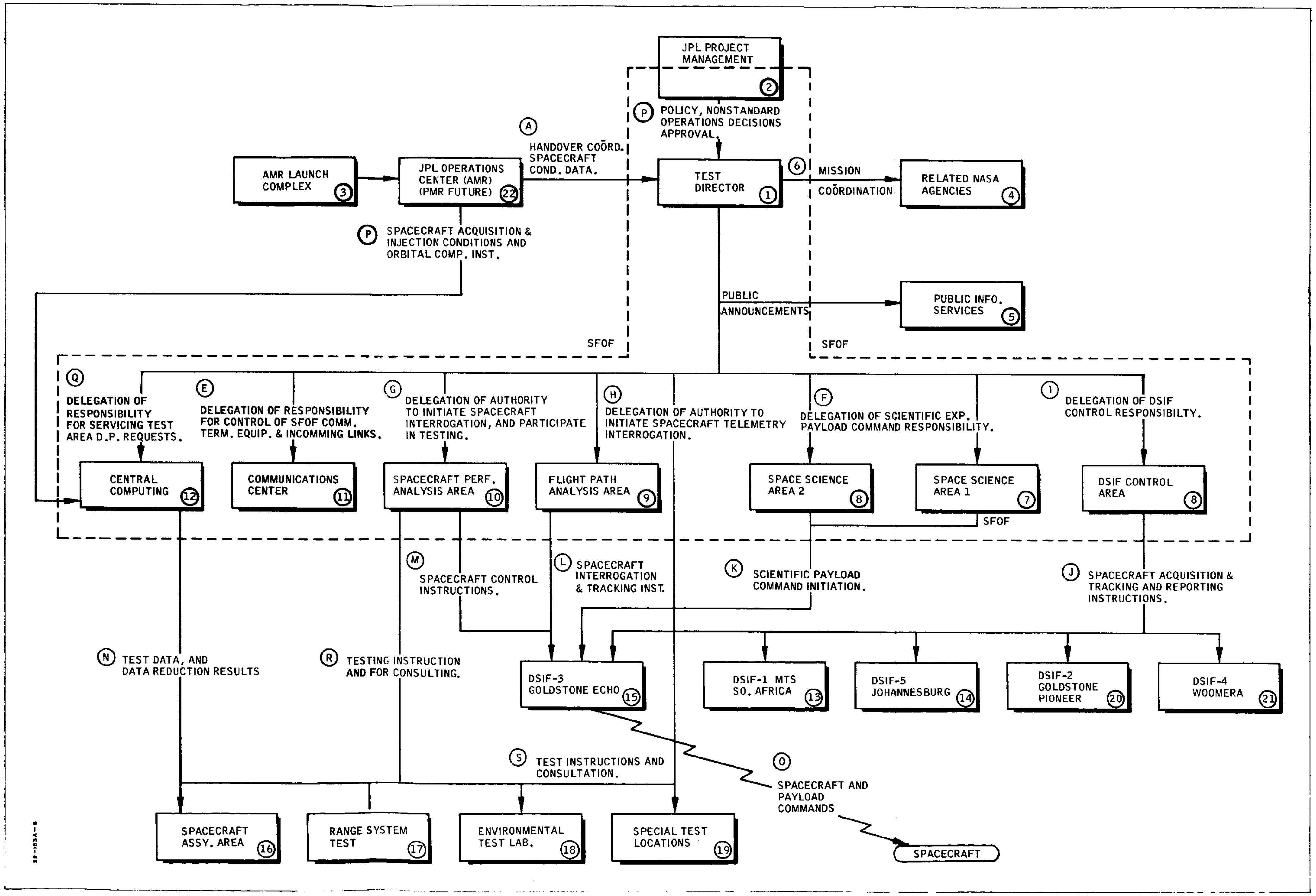

Figure B.2-1 JPL-SFOF External Communications Hierarchy

1.10 DSIF Control instructions are issued by the DSIF Control area on the basis of its own decisions, or in response to specific instructions of the Test Director. These instructions include acquisition and tracking, communications utilization, utilization of, or change in procedures during nonstandard operations, and special start and stop transmission orders.

1.11 "Execute" commands affecting the scientific experiments abroad the space-craft will originate, at the Test Director's option, within one of the two space science areas. These will be transmitted along with their time of activation to DSIF's with command transmit capability. At present, the only one with this capability is Number 3, Goldstone Echo.

1.12 Commands for spacecraft guidance telemetry interrogation will, at the Test Directors option, originate within the Flight Path Analysis area and be transmitted to the DSIF that will transmit the command to the spacecraft.

1.13 Commands initiating midcourse maneuvers, antennae extension and rotation, and orientation of the spacecraft will, by delegated responsibility or specific instruction of the Test Director, originate within the Spacecraft performance Analysis area and be transmitted to appropriate DSIF.

1.14 Support of Pre-flight tests will be provided by the SFOF. In some cases, the Test Director and/or the Spacecraft Performance Analysis area may monitor, control or consult on these tests. The central Computing System will provide computational support.

1.15 Earth to Spacecraft Commands will be issued by DSIF's possessing command transmit capability and situated within line of sight of the spacecraft. These commands will include: midcourse maneuver initiate and terminate instructions along with axis values, other real time commands, scientific experiment payload commands (both real time and stores), and initiate commands for spacecraft stored commands.

1.16 Overall responsibility for a given project lies with the project Manager, The Test Director may have decision authority delegated to him for test operations or may require approval of the project Manager for execution of some decisions.

1.17 Data Processing support to pre-flight tests is frequently provided by the SFOF. When this involves nothing more than servicing processing requests, and when no conflict with real-time operations is expected, the Test Director may delegate responsibility for meeting these requests to the Central Computing Facility.

1.18 Test Instructions and/or technical consulting may be provided to pre-flight test facilities by the SFOF's spacecraft Performance Analysis Area.

1.19 Overall responsibility for the conduct of pre-flight test lies with the project manager. He may delegate responsibility to the Test Director.

2.0 FUNCTIONS

2.1 Test Director. The Test Director is responsible for test operations. He controls the operation of the various operating areas, the remote DSIFs, and the remote test areas. He may frequently coordinate his decisions with JPL technical management, related NASA agencies, and the AMR launch. In the vehicle control hierarchy, he is on a par with AMR launch control: taking over control of the space vehicle after AMR has launched it in its trajectory.

2.2 JPL Technical Management. The JPL Project Manager has overall responsibility for all aspects of the project including the SFOF controlled mission.

2.3 AMR Launch Complex. AMR carries the responsibility of launching the spacecraft and injecting it into its trajectory. Once this has been accomplished, the spacecraft becomes the responsibility of the SFOF and the Test Director.

2.4 Related NASA Agencies. NASA itself, and many of its technical agencies, will carry some decision pregroative in the utilization of the spacecraft. Before making decisions concerning trade-offs in the utilization of the spacecraft and its payload, the Test Director may wish to consult with these agencies.

2.5 Public Information Agencies. Usually, the public information agencies will be monitoring the progress of each space probe. The Test Director or Project Manager will prepare or approve all releases of information to them.

2.6 DISF Control. DSIF control is located in the SFOF. It has the responsibility of controlling the operation of the DSIFs. It also must keep the Test Director informed of the operating status of each DSIF.

2.7 Space Science Area 1. This area is responsible for monitoring and, at the direction of the Test Director, controlling the scientific experiments which are contained in the spacecraft payload.

2.8 Space Science Area 2. This area is identical to 7 above. There are two of these areas in order to accomodate two space missions simultaneously or in close serial sequence.

2.9 Flight Path Analysis Area. This area is responsible for the precise determination of the flight path of the spacecraft. It utilizes both tracking and telemetry data in the performance of flight path analysis.

2.10 Spacecraft Performance Analysis Area. This area is responsible for monitoring and analyzing the performance of the spacecraft and its payload. It must keep the Test Director informed of this performance. Under instructions of the Test Director, it may initiate vehicle commands.

2.11 Communications Center. This area controls, maintains, and operates the communications equipment for the SFOF. It monitors incoming messages and informs the Test Director of the status of its own communication equipment as well as the status of the incoming communication links.

2.12 <u>Central Computing</u>. This area contains all the automatic computational machinery for the SFOF. Its electronic memory and high speed computational capabilities support the operational and scientific activities of the SFOF. During pre-flight testing, it will frequently perform data reduction and computational tasks for the various test locations.

2.13 <u>DSIF-1 South Africa Mobile Tracking Station</u>. This station contains a 10 foot, high angular velocity dish. It is the first DSIF to begin tracking the spacecraft.

2.14 <u>DSIF-5 Johannesburg DSIF</u>. This station has the 85 foot, low angular velocity dish. At present, it has tracking and reception capability only.

2.15 <u>DSIF-3 Goldstone Echo</u>. In addition to the tracking and reception capabilities listed for 14 above, this station has command transmit capability.

2.16 <u>Spacecraft Assembly Facility</u>. This facility is responsible for the final assembly and check-out of each spacecraft. It will frequently require data processing support from the SFOF, and its activities may be subject to decisions to the Test Director.

2.17 <u>AMR System Test Facility</u>. This facility is responsible for the final pre-flight check-out of the total system, both spacecraft and booster. It may frequently call upon the data processing area of the SFOF for support. Decisions concerning further system testing and decisions to launch may be made in conjunction with the SFOF Test Director.

2.18 <u>Environmental Test Lab</u>. The Test Director will frequently monitor environmental test, and may be called upon in decisions concerning further or re-oriented testing.

2.19 <u>Special Test Locations</u>. There is a distinct possibility that spacecraft component or subsystem tests may be carried on in locations other than the three mentioned above. In this case, it is quite possible that the SFOF may provide data processing support, and that the Test Director or his delegates will be kept informed of the nature and progress of the test.

JPL-SFOF COMMUNICATIONS STUDY-PHASE I FINAL REPORT

APPENDIX B, PART 3

INTERNAL COMMUNICATIONS HIERARCHY
(As of 11 June 1962)

1.0 INTRODUCTION

1.1 The accompanying diagram Fig. B-3-1 indicates the principal work areas and/or functions involved in conduct of operations at the SFOF. Also, some of the more important support and ancillary functions are indicated. Concern, here, is only with the internal operations of the system. The chart is constructed so as to give some idea of the levels of control exercised at each of the positions.

1.2 At this point in the development, a few words for each of the more important areas will serve to clarify the construction.

2.0 OPERATIONS CONTROL ROOM

2.1 Control of the space flight operations centers in this room. During operations, the room is continously staffed by one or two Test Directors. In normal operation, the Test Director has full responsibility for conduct of the test. To fulfill this responsibility, he must be able to control, coordinate, and monitor all operational activities pertinent to the conduct of the space flight operations and tests. Also, he, or his representative, will have such ancillary functions as that of Public Information. This will be discussed later. A console is provided each Test Director to give him the required capabilities.

2.2 Two Test Directors may be present in the Operations Control Room. This will occur when it is necessary, or desirable, to carry out two space missions simultaneously. The rest of the system will also have this capability.

2.3 As has been noted, the Test Director normally carries full responsibility for the SFOF operations. However, the Project Manager has over-all responsibility for all aspects of a project. And, he may exercise control of operations from the same Control Room.

3.0 OPERATIONS AREA

3.1 This is the focal point for the conduct of real time operations. Primarily, this is a central source of information. As such, the Area will contain a variety of displays. These will include displays for events, trajectory, operational status of the vehicle and SFOF systems, and a data-processing display. It is likely that a hard-copy capability will also be available.

3.2 In special cases, Customer Engineering may provide the Area with specialized equipment peculiar (and necessary) to a particular mission. This facility may be similarly used in any portion of the SFOF, though it is most likely here.

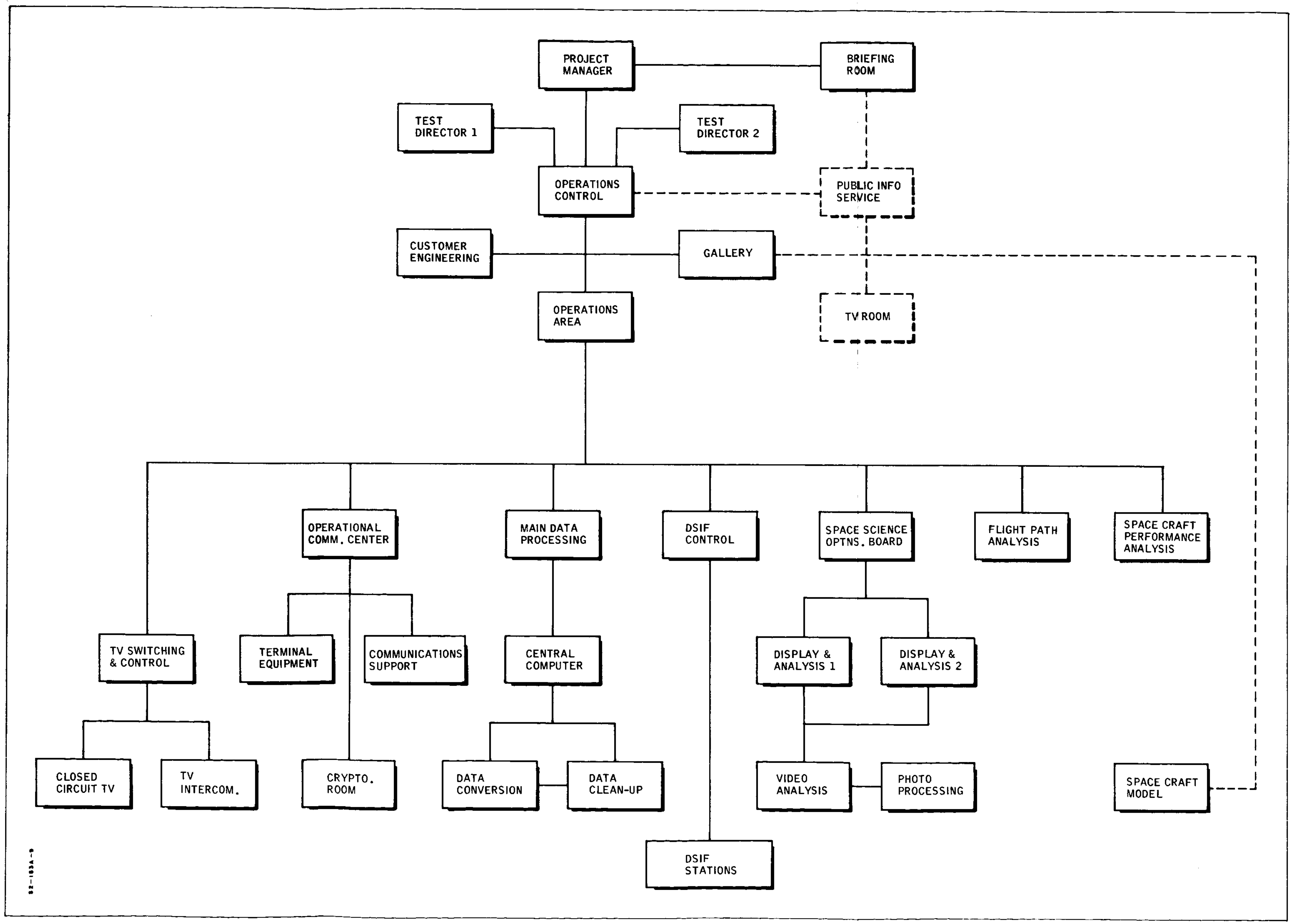

Figure B.3-1 JPL-SFOF Internal Communications Hierarchy

4.0 OPERATIONAL COMMUNICATIONS CENTER

4.3 Basically, this area is responsible for the communications and the communications equipment of SFOF. This applies to both the internal SFOF communications system; and the necessary communications external to the SFOF itself. In carrying out its responsibility, the Center controls, maintains, and operates the communications systems. The Operations Area is notified of the Status of these systems.

4.4 Envisioned operations of the SFOF may at some future time require that some of the communications be encrypted. In this function, the Communications Center will be supported by the facilities provided in the Crypto Room. The Terminal Equipment room will, of course, contain the terminal equipment necessary to the SFOF Communications System. Most of the general communications support is handled by the Communications Support area; which is capable of taking care of most of the routine traffic.

4.5 Normally, the Communications Center is responsible to the Test Director. However, the Center may be granted autonomous responsibility by the Test Director. This will normally be granted for routine communications decisions. Delegation of this responsibility must be supported by information which will include factors such as: current status of the mission, detailed objectives, and predictions of the likely system responses.

5.0 MAIN DATA PROCESSING

5.1 This area will process all tracking, telemetry, and operational data for both space-flight operations and space-craft tests. In so doing, the area furnishes any, and all, the other technical areas with computational support. A console will be provided for operation control of the data processing system. This may include the equipment necessary for operating displays integral to the console and those in the Operations Area.

5.2 The Central Computer for the data processing system will be programmable, Many programs will be available. These are likely to be priority-tagged. There may also be a schedule tag; this would be for the purpose of operating on a sequence of programs.

5.3 The data processing system is supported by the Data Conversion Area. Its principal function is to format the incoming data. However, it will also provide some buffering and a very limited computational capability.

5.4 Incoming data will not always be as expected. Its quality may be degraded by faulty equipment performance and general noise. Data Clean-up furnishes the data processing system with off-line support for the purpose of salvaging degraded data of special importance.

5.5 Ordinarily, the priority-tagging of the computer programs is the responsibility of the Data Controller; and he has the capability for changing the priority of any particular program. In routine operations, such as might occur in non-real time operations, the Test Director may relinquish this resonsibility, with the accompanying capability, to the Main Data Processing Area. With regard to requested support for pre-flight tests, the Test Director will again delegate authority for meeting these requests when they do not conflict with real time operations.

6.0 DSIF CONTROL

6.1 The function of this area of the SFOF is to monitor and control all communications to and from the DSIF stations. Thus, it will be in parallel with the data flow to and from these stations. DSIF Control will have the capability for denying access (selectively or comprehensively) to the DSIF communications lines. As is the case with all the technical areas, DSIF Control must also keep the Test Director informed of DSIF status. The requirement for status reporting may be more critical here than with some of the other areas. Efficient operation will require direct communication links to the Operations Area, the Space Flight Area, and the Communications Center.

6.2 Authority for this Control may, in routine or peculiar circumstances, be delegated by the Test Director. This will require that the DSIF Control Area be able to obtain information on (1) status of the entire SFOF system, and (2) the immediate objectives of the mission.

7.0 SPACE SCIENCE OPERATIONS BOARD

7.1 This is really the control point for the Space Science Analysis Area. As such, it is the source for the major decisions regarding scientific experiments which may be part of the mission.

7.2 In the normal hierarchy, the Space Science Operations Board suggests, or recommends, commands to the Test Director. However, it is likely that the Test Director will delegate the authority (to the Board) for issuing commands which affect only the scientific experiments. This will require that the Operations Board be kept current on the activities and status of the other technical areas.

7.3 Evaluation of the experiments is conducted in the Display and Analysis Rooms 1 & 2. Normally, these areas operate on processed data. However, because of malfunctions or the immediacy of analog data, the occassion may arise when raw data is all that is available - or is desirable. It may be desirable when certain forms of analog data can give a quick, qualitative appraisal of the experiment being performed. Hence, these rooms will need access to the raw data - there will be no need for a continual flow.

7.4 Of course, the Display and Analysis Rooms also function in a support capacity to the Space Science Operations Board. They will furnish the Board with the information needed to arrive at the major decisions and commands.

7.5 The Video Analysis Room obtains the real-time video data and analyses it. It is capable of simultaneously displaying real-time video data and previous information. In this way, this room serves as support to the above Analysis Rooms 1 and 2.

7.6 A Photo Processing capability is provided to support Video Analysis by providing permanent copies of the incoming real-time video data.

8.0 FLIGHT PATH ANALYSIS:

8.1 The function of this area is to determine and predict the flight path of the space craft. The prediction information is relayed to the tracking stations through the required controls.

8.2 Since the function of this area is extremely time-critical, raw tracking data will be fed to Flight Path Analysis and the data processing system, similtaneously.

8.3 Another function of this area will be to generate all commands which are determined by, and which may also determine, the flight path of the space craft. These commands will, in the normal hierarchy, be recommended to the Test Director for implementation. However, at his option, the Test Director may delegate the authority for these commands to the Flight Path Analysis group. This will occur only at non-critical times.

8.4 These Flight Path Commands, as with all the other areas, require access to status and objective information on the system as a whole. However, most especially in the case of the Flight Path computation, information must be current as to the Space Craft status. This will require close liaison with the Space Craft Performance Analysis area.

9.0 SPACE CRAFT PERFORMANCE ANALYSIS:

9.1 The function of this area is closely tied to the Flight Path Analysis area. Space Craft Performance Analysis determines the performance of the space craft. And, the area will make command and operational recommendations to the Test Director.

9.2 Responsibility for Commands, and its delegation by the Test Director, have the same requirements as with Flight Path Analysis. However, here, the area's ability to issue pertinent commands depends critically on having information on the current and predicted Flight Path.

9.3 A separate room is provided for the Space Craft Model: which is actually a large-scale model of the space craft with relation to the celestial sphere. The model will realistically display both the position of the space craft, and the relative position of its articulating numbers. In addition to being an aid to the analyses, the model will be viewable by the public via the Lobby.

10.0 TV SWITCHING AND CONTROL:

10.1 This area, which may later come under control of the Communications Center, serves as the control position for the TV systems which may become part of the SFOF system. Physically, the control will be near the Operations Area. And it is likely that this area will be under the responsibility of a representative for the Test Directors.

10.2 Part of the TV system would be a Closed-Circuit TV set-up. The function of this is to provide any of the technical and operation areas with an immediate view of any part of the Displays in the Operations Area.

10.3 The TV Intercom functions exactly as its name implies. This system operates as a visual intercom throughout the technical and operational areas of the SFOF. Each of the areas will have a TV Camera and a Monitor. These will all connect back to the switching central. It is still a question as to what control is to be exercised over the camera position. Will the position be controlled by the switching center? Will the transmitting camera position be controlled by the calling area? Will the transmitting camera position be controlled by the answering area? Or will the camera positions be fixed (possibly, indicating critical dynamic information)? If these questions can be resolved, there is still the problem of resolution. This equally applicable to both TV systems. At the moment, it seems questionable that the resolution of a TV system will offer the receiver any really useful information.

11.0 BRIEFING ROOM

11.1 Essentially, this is a small, on-the-spot, conference room. And, it will be available to the Project Manager for holding operational conferences with his Advisors. The room will also serve in a public relations capacity by providing facilities for brief, on-the-spot, interviews.

12.0 GALLERY

12.1 Project Personnel, and some limited number of other individuals, may be required (or allowed) to observe operations. To facilitate this, the Gallery is provided. It will overlook the Operations Area and the immediately adjacent areas.

12.2 Permission for entering the Gallery will probably be under direction of the Test Directors and/or the Project Manager.

13.0 PUBLIC INFORMATION SERVICE

13.1 The information to be released to the public, by whatever media, will be strictly controlled by the Test Director (and/or Project Manager), or his representative.

13.2 News releases to small groups will probably be carried out in the Briefing Room. If the group is large, and the Gallery is not being otherwise used, the Gallery might be used for the news releases. In this case, the viewing capability might be screened off.

13.3 Under some circumstances, the Gallery might be offered to the public for observing the operations. This is highly unlikely, however. It is more likely that this sort of public relations would be carried out via the TV Room.

13.4 The TV Room offers video coverage of the operational area. The video signal is available for use in remote auditoriums, where large audiences can be handled. The signal is also available for use by commercial facilities.

13.5 The Space-Craft Model, used by Space-craft Analysis, is also arranged to serve as a display for the public. It is viewable from the lobby.

JPL-SFOF COMMUNICATIONS STUDY-PHASE I FINAL REPORT

APPENDIX B, PART 4

QUALITATIVE INFORMATION EXCHANGE REQUIREMENTS
(As of 25 June 1962)

1.0 INTRODUCTION

For the purposes of this paper, "data" is defined as that information which normally requires computational processing. (There are exceptions to this norm.) Thus, it excludes general administrative information and most voice traffic.

The first step will be to present a chart, Figure B. 4-1 tracing the actual flow of data through the SFOF. At least for discussion, this will be simplified by defining three broad categories of data - Real Time, Command, and Non-Real Time.

The second step will be to present some idea of the kinds of data which are initiated at the user areas. Also, an attempt will be made to obtain some idea of the kinds of data used (or required) at the various operational areas of the system. These will not be exhaustive; and, at present, are intended only as a qualitative indication.

2.0 DATA FLOW

2.1 DATA CATEGORIES

In the operation of the SFOF, there will be three broad categories of data flowing. These are: Real Time Data, Command Data, and Non-Real Time Data.

The principal characterization for Real Time Data is that its processing is as near to real time as possible. The data enters the data-processing system in real time. It is then processed and displayed as expeditiously as computer capability, priority assignments, and programs will allow.

Command data is intended to initiate action in the external parts of the system - as Spacecraft, DSIF station, Test Site, and/or Launch Facility. These data will be originated by the Analysis Areas, DSIF Control, and/or the Test Director.

The Main Characteristic distinguishing Non-Real Time Data is its delayed processing. The data may be received from the normal communications links to the remote sites; or, it may be received on mailed magnetic records. The processing results are prepared off-line of the main data-processing.

2.2 REAL TIME DATA FLOW

Most of the incoming data will come from the DSIF sites. In general, this data will be separated, digitized, and formatted. However, some of it may be raw data. DSIF, in turn, received most of its data from the

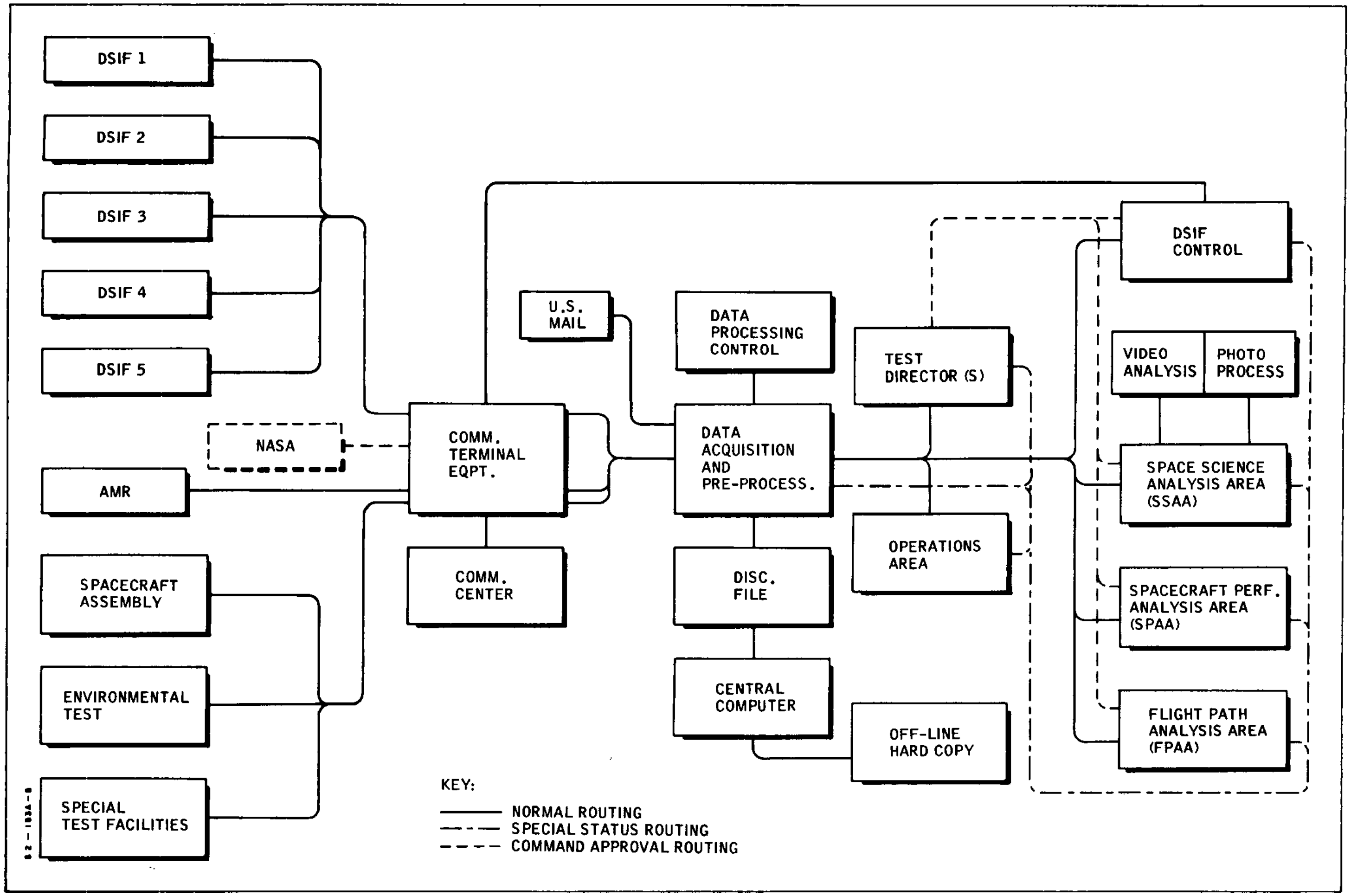

Figure B.4-1 SFOF Qualitative Data Flow

spacecraft. It was then in the form of a composite TV Telemetry signal. The telemetry included both engineering and scientific data. To this data, the DSIF will also add the acquired tracking data; and its station status information. Some of the incoming data will also come from the test sites and the AMR launch site. They will be of a similar nature, but much less in quantity.

All incoming data will be recorded as soon after entering the terminal as possible. This will save the data in the event of a malfunction further along the data-processing line.

The data must be further formatted so that it may enter the Central Computing Facility. This will be accomplished in the pre-processor. If the data requires, telemetry recovery will have to be performed before entering pre-processing.

After pre-processing, the data is again entered into tape storage. This will serve as a recovery back-up. In addition, the data will be entered into a disc file for use by the pre-processor and the central computer.

The central data-processor uses the disc data as the operational programs require. The computational results are then re-written into the disc file for use by the pre-processor. The computational results are also written onto a magnetic tape store. This store can be used to furnish off-line hard copy when requested.

The pre-processor (now, really an I/0 processor) then performs its routing function. Some of the routing will be done on a fixed program basis. This will include routing of the data for driving status displays for the various systems and sub-systems of the complex. A special case is the video data received by SFOF. This will be routed directly to the Video Analysis group in the Space Science Analysis Area. (Some of it will be hard-copied by photo-processing.)

The pre-processor will also perform routing on a request basis. A special case of this is that of raw data. Any one of the Analysis Areas is likely to request that it be given raw data (where the raw data is analog probably). Particularly, the Flight Path Analysis Area will want to receive the raw tracking data.

The user areas will have a capability for remote input to the data-pro processing system. This will be used to initiate the requests for special displays. Also, the remote input enables the analysis areas to insert data into computer programs.

2.3 COMMAND DATA FLOW

Commands may originate at any of the Technical areas or at the Test Director position. One class of commands will require approval of the Test Director before transmission. The other class of commands does not require Test Director approval. The class to which a particular command belongs will depend on the phase of the mission; and the type of command.

Commands requiring approval are indicated as flowing to the Test Director. In fact, however, these commands will go the the pre-processor where it is temporarily stored. The pre-processor will present the requested command to the Test Director. (He may require additional data to be presented at the same time.) If the Test Director enables the command, the pre-processor will prepare it into the correct format for transmission. Commands not requiring approval go the same route without requiring a Test Director enable. In both cases, all commands and transmissions readiness are displayed in all technical and operational areas.

After preparation, the command is transmitted to the designated site. If the command is for the spacecraft, DSIF will transmit the required signal.

In the event that confirmation is required, the command is played back from the spacecraft through DSIF. The playback returns directly along the flow. It will be displayed at all interested areas. The playback may also affect some of the status displays.

2.4 NON-REAL TIME DATA FLOW

Processing of this data will not require inputs from the analysis areas. And there is no requirement for a rapid display capability.

There are two possible modes for data to enter the system. In the first mode, data enters the pre-processor in the same manner as real time data. However, the disc file is not used; and the pre-processor enters results on tape only. In the second mode of entry, the data is recorded onto magnetic tape at the remote sites; and the tape is mailed to SFOF.

These entry tapes are then batch-processed on the central computer. The computed results are entered onto other magnetic tapes. These output tapes will then drive off-line displays in the form of volume hard-copy and microfilm records.

3.0 DATA DESCRIPTION

In following the data flow, it is evident that as far as physical paths are concerned, the central data-processing is the source and a sink for most of the data within the complex. Functionally, this is not true; and, thus, this concept does not give a very clear picture of data requirements.

In the data listings which will follow, the computer facility will be considered as essentially a switching terminal. Where a user area is presently responsible for a computer program, he will be considered as the source for the results of that program. Where a user area draws on the results of a program for which he is <u>not</u> responsible, the listing will consider the results as having been received from the area responsible for that particular program.

3.1 DSIF STATIONS

3.1.1 BASIC FUNCTIONS

To track the spacecraft, and receive the transmitted telemetry.
To keep SFOF informed on acquired information, and station status.
Transmit required commands to the spacecraft.

3.1.2 Received from Spacecraft

A. Composite TV/Telemetry signal
   1) TV data
   2) Engineering Telemetry
      a. Fuel Supply
      b. power supply(s)
      c. attitude control system
      d. communications system
      e. computer/sequencer system
      f. mid-course guidance system
      g. terminal maneuver system
      h. telemetry system
      i. etc...
   3) Scientific Telemetry
      a. seismograph
      b. spectrometer
      c. temperature
      d. earth sampling
      e. biological experiments
      f. etc...

B. Playback of Commands and/or Command Accomplishment

3.1.3 Receives from AMR (via DSIF control)

A. Prior to Launch
   1) Spacecraft conditions
      - telemetry sync., transponder freqs. etc...
   2) Countdown status
B. Post Launch
   1) nominal trajectory data
   2) acquisition angles - based on 1st burn

3.1.4 Receives from DSIF control

A. Commands for spacecraft
B. Prediction of data to be received
C. Acquisition angles
D. Transmitter frequency
E. Communication line selection
F. Maybe "Drive Tape" control for Antenna
G. General Administrative data
   - logistics, organization, personnel, etc....

3.1.5 Transmits to Spacecraft

A. Commands directed by DSIF Control

3.1.6 Transmits to SFOF

A. Separated, Digitized, and otherwise formatted data
   1) Doppler and Angle Data
   2) All Spacecraft Telemetry
   3) Time tag for telemetry

4) Spacecraft TV
5) Signal Strength
6) Station Status - condition and utilization
7) Playback of Command to Spacecraft, possibly

B. Raw, unseparated TV/Telemetry Composite
C. Mails Data for post-operational use
   - includes all raw data generated and received
D. General Administrative data required for system operation

3.2 LAUNCH SITE - AMR

3.2.1 Receives from SFOF

A. Facility status
   1) go
   2) no go

3.2.2 Transmits to SFOF

A. Prior to Launch
   1) Spacecraft conditions
      - telemetry sync., transponder freq., etc...
   2) Countdown status

B. Post launch
   1) nominal trajectory data
   2) acquisition angles - based on 1st burn

3.3 DSIF CONTROL

3.3.1 Basic Functions

A. Operational control of all data to and from DSIF sites.
B. Control of any and/or all DSIF communication lines at any time.
C. Identify any DSIF Information not recognized by data-processing.

3.3.2 Receives from DSIF Stations

A. Operational Status 6-12 hours prior to launch
B. Station Status every 20 minutes during first 24 hours
   1) condition
   2) utilization
C. Acquisition and tracking data

3.3.3 Receives from Flight Path Analysis Area (FPAA)

A. Pointing information for acquisition
B. transmitter frequency
C. Ground mode for DSIF
D. Prediction of data to be received
E. "Drive tape" for antenna control, maybe
F. Maneuver Commands for spacecraft
   - come from Maneuver Command Unit

3.3.4 Receives from Spacecraft Performance Analysis Area (SPAA)
  A. Commands for Spacecraft
    1) attitude
    2) communications
    3) temperature control
    4) etc...

3.3.5 Receives from Space Science Analysis Area (SSAA)
  A. Spacecraft Commands affecting scientific experiments

3.3.6 Transmits to DSIF stations
  A. Relay from AMR
    1) spacecraft conditions prior to launch
      - telemetry senc., transponder freqs., etc...
    2) up-to-date countdown status
    3) acquisition angles based on 1st burn
  B. Instructions and Commands
    1) based on inputs from FPAA, SPAA, SSAA listed above

3.3.7 Transmits for SFOF use (Test Director, Ops, Area, SSAA, FPAA, Communications)
  A. DSIF status information
    1) condition of each station
    2) utilization of each station
      - tracking, listening to telemetry, ground mode being used, what probe being tracked by what station, etc...

3.3.8 Transmits to Data-Processing
  A. Identification of "bad" DSIF data

3.4 COMMUNICATIONS CONTROL

3.4.1 Basic Functions
  A. Provide necessary terminal and switching equipment
  B. Maintain switchboards
  C. Identify unrecognizably formatted data

3.4.2 Receives from Test Director
  A. Identification of non-standard operation

3.4.3 Receives from User Areas
  A. Information pertinent to identification of poor format data

3.4.4 Transmits to Test Director and Operations Area
  A. Communication System Status
    1) Operational state for each line
      - in, out, or marginal
    2) Utilization for each line
      - tracking, telemetry, or administrative data
      - administrative or operational voice traffic

3.4.5 Output for general use
- A. May have strip-chart analogs available (on request) of incoming data

3.4.6 Transmits to Data-Processing
- A. Identification of poor-format data

3.5 DATA-PROCESSING CONTROL

3.5.1 Basic Functions
- A. Handle, process, and display all tracking, telemetry, and operational data.
- B. Scheduling and processing of all data according to the Space Flight Operations Programs (SFOP), and non-standard requests

3.5.2 Basic Inputs
- A. Data after Telemetry Recovery
- B. Raw data
- C. Inquiries from User Areas
- D. Program insertions from user

3.5.3 Received from DSIF and/or Communications Control
- A. Identification of "bad" data

3.5.4 Basic Outputs
- A. Processed data routed as per SFOP or special non-standard requests.
- B. Raw Data routed to using technical areas

3.5.5 Transmits to Test Director/Operations Area
- A. Data-Processing System status on sub-system basis, conditions and utilization of
  1) I/O Processor
  2) Disc File
  3) Central Computer
  4) Tape Storage

3.6 SPACE-SCIENCE ANALYSIS AREA

3.6.1 Basic Function
- A. Analyze and interpret all data related to the evaluation of scientific experiments during test operation, flight operation, and post-operational analysis.
- B. Make decisions and recommend commands affecting scientific experiments.

3.6.2 Receives from Spacecraft
- A. Raw video and analog telemetry related to science experiments
  1) TV
  2) scientific experiments whose telemetry is analog
- B. Processed data for scientific experiments
  1) seismograph
  2) spectrometer

3) temperature
4) earth sampling
5) biological experiments
6) etc....

3.6.3 Receives from Spacecraft Performance Analysis Area (SPAA)
A. Spacecraft status of selected subsystems
1) power supply(s)
2) attitude control
3) telemetry system
4) etc...

3.6.4 Receives from Flight Path Analysis Area (FPAA)
A. Trajectory information
B. Maneuver Determinations by maneuver command unit

3.6.5 Receives from All Areas (via Data-Processing)
A. Commands for the Spacecraft and their readiness

3.6.6 Transmits to DSIF Control
A. Spacecraft Commands affecting scientific experiments - may require approval of Test Director

3.6.7 Transmits to Maneuver Command Unit (FPAA and SPAA)
A. Recommendations and/or requests for maneuvers optimizing scientific experiments

3.6.8 Internal Information use
A. Display of future events and immediate past
B. Historical display on each experiment
C. Display of future alternate action paths
D. Video Analysis Room
provides real-time display of TV data from spacecraft
E. Photo-processing room
provides video-analysis with hard copy of past views for comparison may provide hard-copy print for general distribution

3.7 SPACECRAFT PERFORMANCE ANALYSIS AREA

3.7.1 Basic Functions
A. Analyze, evaluate, and interpret all data related to performance of spacecraft.
B. Support Flight Path Analysis Area and general space flight operations.

3.7.2 Receives from Spacecraft
A. Processed telemetry (engineering) via data-processing detailed in status display
B. Doubtful, but may use raw data

3.7.3 Receives from Flight Path Analysis Area (FPAA)
A. Trajectory Information
B. Maneuver Determinations by Maneuever Command Unit

3.7.4 Receives from Space Science Analysis Area
- A. Recommendations for commands optimizing science experiments

3.7.5 Receives from All Areas (via Data-Processing)
- A. Commands for the Spacecraft and their readiness

3.7.6 Transmits to DSIF control
- A. Spacecraft Commands affecting spacecraft performance - may require Test Director Approval
  1) Attitude control
  2) Temperature Control
  3) Communications Control
  4) etc....

3.7.7 Transmits to Maneuever Command Unit (FPAA)
- A. Information relative to spacecrafts capability for performing maneuever.

3.7.8 Transmits to Test Director via Status Board
- A. Spacecraft subsystems status
  1) fuel supply
  2) power supplies
  3) attitude control systems
  4) telemetry system
  5) mid-course guidance system
  6) terminal maneuever system
  7) communication system
     - transmitter power
     - signal levels
     - AGC
     - doppler plots
     - phase center
  8) etc...

3.7.9 Transmits to Flight Path Analysis Area
- A. Status of selected subsystems
  1) fuel supply
  2) power supply
  3) attitude control system
  4) etc...

3.7.10 Output for general use
- A. Maintains Spacecraft-Celestial Sphere model.

3.8 <u>FLIGHT PATH ANALYSIS AREA</u>

3.8.1 Basic Functions
- A. Analyze, evaluate, and interpret tracking data.
- B. Determine orbit and required corrections; and compute trajectory

3.8.2 Receives from DSIF - via DSIF control
A. Raw tracking data from the tracking stations
B. Initial conditions from AMR
- nominal trajectory data

3.8.3 Receives from Spacecraft Performance Analysis Area
A. Status information on selected Spacecraft subsystems
1) fuel supply
2) power supply
3) attitude control system
4) etc...

3.8.4 Receives from Space Science Analysis Area
A. Recommendations for commands for maneuevers which will optimize science experiments

3.8.5 Receives from All Areas (via data-processing)
A. Commands for the Spacecraft and their readiness

3.8.6 Transmits to DSIF - via DSIF control
A. Pointing Information for acquisition
B. Transmitter frequency
C. ground mode for DSIF
D. Prediction of data to be received
E. "Drive tape" for antenna control, maybe

3.8.7 Transmits to Spacecraft - via DSIF Control
A. Commands affecting Flight Path

3.8.8 Transmits to Maneuver Command Unit
A. Consultation and advise on possibilities and limitations of alternate trajectories

3.8.9 Transmits to SSAA and SPAA
A. Trajectory-derived plots as required

3.8.10 Transmits to Test Director
A. Orbit and trajectory determinations
B. Recommendations for future patterns for gathering tracking data. - implemented in a display of earth, target, & spacecraft trajectory

3.9 OPERATIONS AREA/STATUS BOARD

This is purely a display area. As such all data is both input and output. The data requirements in this particular instance are best explained by briefly describing the displays in the area.

3.9.1 Basic Functions
A. To serve as a centralized location for information.
B. To allow the Test Director to group representatives from the technical areas for centralized conduct and execution of operations.

3.9.2 Pre-injection Events Display

This will probably include the information transmitted from AMR, with reference to pre-launch conditions.

3.9.3 Spacecraft Status Display

A. Data controlled by SPAA
B. Status will be on a subsystem level
   1) fuel supply
   2) power supplied
   3) telemetry system
   4) mid-course guidance system
   5) terminal maneuver system
   6) communication system
   7) etc...

3.9.4 Post-Injection Events Display

A. Data controlled by SPAA and FPAA, primarily
B. Items to be included
   1) Geometric DSIF View Periods
   2) DSIF view periods scheduled
   3) Spacecraft post-injection event
      - actual and standard

3.9.5 Trajectory Information

A. Data controlled by FPAA
B. Alpha-numeric information
C. Graphic display of trajectory - with possibly confidence limits

3.9.6 Special Events Display

A. Displays non-standard events and items of special interest
B. Will have to include a capability for displaying any selected portion of the Data-Processing System output.
C. Selection will be done by Test Director or his representative.

3.9.7 Communications System Status Display

A. Operational condition of each line between SFOF and the remote station. In terms of in, out, or marginal.
B. Utilization of each such line
   - tracking, telemetry, or administrative data
   - administrative or operational voice traffic
C. Data controlled by Communications Control

3.9.8 DSIF Station Status

A. quantitative information on station condition
B. Utilization of each station
   - tracking
   - listening to telemetry
   - ground mode in use
   - what probe being tracked by what station
C. Data controlled by DSIF Control

3.9.9 Data-Processing System Status

A. Condition and utilization of selected subsystems

1) I/0 Processor
2) Disc File
3) Central Computer
4) Magnetic Files
5) Programs in use
6) etc...

3.9.10 Clocks-Time Display

A. Information to be included

1) GMT, 24 hours
2) Countdown and Count-up Clock for timing arbitrary events
3) Count-up time from injection
   - days, hours, minutes, seconds
4) Count-up for time from launch
   - seconds

3.9.11 Special Displays

A. These may be required when the mission has some unique characteristics to be monitored.

3.10 TEST DIRECTOR

3.10.1 Basic Function

A. Responsibility for over-all direction and co-ordination of activities of SFOF during a mission.

B. Specific Tasks

1) Control the information to go on the Operations Area Status Board.
2) Control the use of data-processing during space-flight operations.
3) Control all commands to the spacecraft.

3.10.2 Receives from Operations Area

A. Status board gives most of his information requirements

B. Additional details need at his console and in the form of consultation.

3.10.3 Receives from All Areas - via Data-Processing

A. All commands for the spacecraft and their readiness

B. Any ancillary data he may request

3.10.4 Receives from all Areas

A. Consultation and Recommendations

1) SSAA - status of current scientific missions
   - Experiments desired in future
   - Command recommendations
2) SPAA - effect of spacecraft status on future objectives
   - Command recommendations
3) FPAA - Status of Orbit and/or Trajectory
   - recommended patterns for gathering tracking data
   - Command recommendations

4) DSIF - tracking station capabilities
- recommendations for future operations

B. Total should result in operating status of subsystems of SFOF.

3.10.5 Receives display of SFOF events

A. Present events
B. Immediate past and future
C. What events scheduled to occur when?
1) Did they occur?
2) If not, why not?

3.10.6 Outputs and/or specific tasks

A. Prepared Space Flight Operations Plan (SFOP) prior to mission.
B. Authorizes any alterations to the SFOP required by a non-standard events.
C. Schedules activities of Data-Processing
1) Authorizes changes in data-processing program priorities
D. Enables selected, or all, spacecraft commands
1) Selective authorization depends on mission and will be defined by SFOP.

4.0 REQUIREMENTS FOR ORAL COMMUNICATIONS

It is impossible to predict with sufficient certainty the character and content of oral communications within the SFOF environment. Typically, they will contain a spectrum of information concerned with:

* Verbal attention call-outs
* Work coordination
* Personnel assignment
* Non-standard operations, and so forth.

Under these circumstances it seems better to suggest criteria for oral communications nets, than to define the content of messages.

The following suggests a number of non-overlapping operations nets based on the SFOF organization and expected operation. These are provided with backup flexibility in two ways. (See Figure B.4-2.)

1. Patching control between nets
2. A back-up dial PBX system.

4.1 NET NO. 1

Each Test director and operations area director is included in a priority conference net. Each member is able to call direct to any other member or members.

4.1.1 The following priorities for actually breaking into conversations or usurping lines in Net 1 should exist:

a. Test Director
b. Operational comm.
c. Main data processing
d. DSIF control
e. Flight path analysis

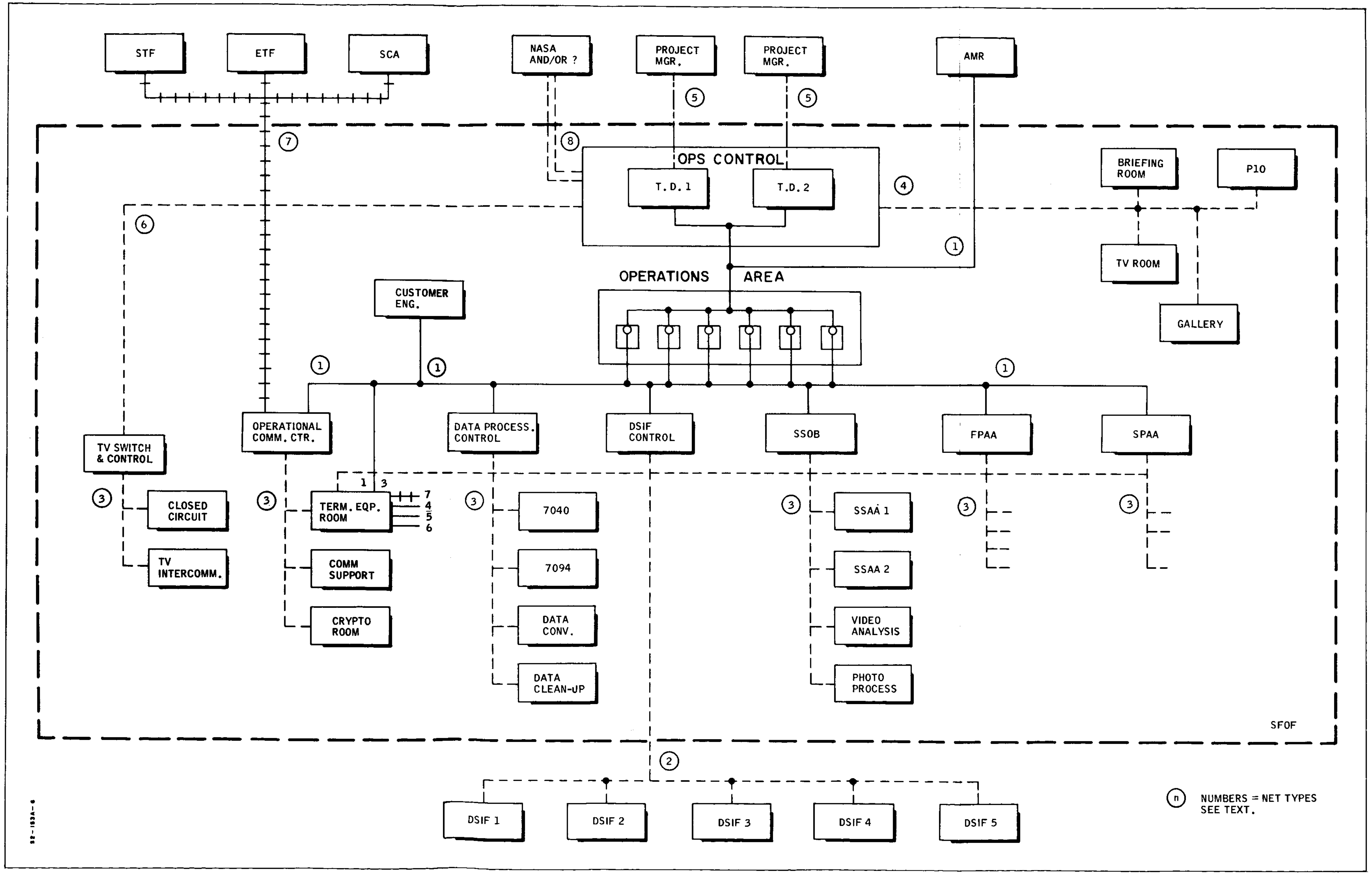

Figure B.4-2 Oral Communication Netting Requirements

f. Spacecraft performance analysis
g. Space science operations board
h. Customer engineering
j. AMR

4.1.2 There must be, in addition, visual indicators with audio attention signals, signifying who is calling each station.

4.1.3 It may be desirable, in addition, to have a manual "break-in allow" switch at each station. This would allow operators at each of the above stations, upon seeing an indicator to:

a. Decide that he did not wish to be interrupted but,
b. The conditions could be such that the call was more important than what he is doing, then;
c. Signify this to the caller and
d. Allow the caller at the caller's discretion to come into his talk line, without breaking the existing connection, in order to confirm this.

4.1.4 This scheme should provide sufficient feedback information content (at relatively low implementation cost) to allow the necessary human decision control over verbal communications that will:

a. Assure that all priority calls get through
b. Maintain the number of unnecessary interruptions at an acceptable level.

4.2 NET NO. 2

A separate direct call and conference net is provided between DSIF Control and the DSIFs'. The DSIF controller may, by switch selection, call any or all of the DSIFs'. Each DSIF would not have this capability.

4.3 NET NO. 3

Each operating area should have its own direct call and conference net. This net is exclusive of any of the other No. 3 nets unless temporary connection has been provided via the Comm. Center at the direction of the Test Director.

4.4 NET NO. 4

A separate point to point and conference net should exist between the operations control area and the P10, Briefing Room, TV Room and Gallery. This allows some relatively long calls to procede on this line without hampering operations.

4.5 NET NO. 5

Direct, separate lines between the office of the project Manager and the test directors positions should be provided. This will allow high priority calls in either direction with minimum delay.

4.6 NET NO. 6

The Test Directors should be provided a direct line to the area that will service or maintain the visual intercommunications net.

4.7 NET NO. 7

The Test Facilities, operating in non-real time, should be on a separate net that feeds into the terminal equipment area, and may then be patched to any operating area(s) as required.

4.8 NET NO. 8

A direct line may, at times, be necessary between some NASA facility or other agency. This would be required when the NASA facility or other agency has some unusual perogative or interest in the operation-- as when the SFOF is acting in a support role.

4.9 Each net should, in addition to the usual routing, be tied into a switching matrix that will allow its temporary connection with any other net. This connection would be under manual control.

4.10 An internal dial PBX system (not shown) should be provided as lower speed or non-priorty backup to the operational nets and for connection to the outside. Thus, non-priority calls would typically occur on this and not on the operational nets.

APPENDIX B, PART 5

QUANTITATIVE INFORMATION EXCHANGE REQUIREMENTS

1.0 INTRODUCTION.

These notes are presented here for possible future use in adaption of the matrix technique to automation and consequent periodic traffic analysis print-outs. Such an approach should be considered for analysis of requirements to assure that the "final" SFOF communication system is not over-designed but provides for all routine, unusual, and emergency communications to include an expansion capability. Enclosure 1 is a recommended outline for a future study and report.

2.0 THE GRID.

The elements which must exchange information are determined. They then are listed down the left side and accross the top of a matrix. Transmission is from those on left to those accross the top. This forms a matrix. See Fig. B-5-1 for further details of the matrix. The actual matrix, full scale, is about 34" x 48".

The nodes of the matrix then have a coded entry which gives details of the information exchange.

3.0 GRID ENTRIES.

In reading the coded entry, the positions are counted from the left. Table B-5-1 then gives the Translation.

The coded entry carries a 5th position, in addition to those of the above Table. This is keyed to the card-index file which carries detail information.

In some entries, several information Classes are indicated in one transmission. This is doen when they are, in some manner, strongly entwined (as in the Spacecraft Signal). The card keyed to this transmission will explain the particular case.

Similarly, when more than one Signal Type are equally likely, all are indicated in the grid entry. Whether these are exclusive or inclusive will be indicated in the associated card. Secondary possibilities, and back-ups, will also be covered in the detail card.

As presently used, the data rates indicate capabilities, not requirements - as would be desireable.

4.0 CARD FILE.

The ultimate in coding would leave nothing more to be desired in the way of information about a particular transmission. In the interests of conciseness of coding - and for the unusual situation - a card file is used. See Table B-5-2 for an abridged copy of card file.

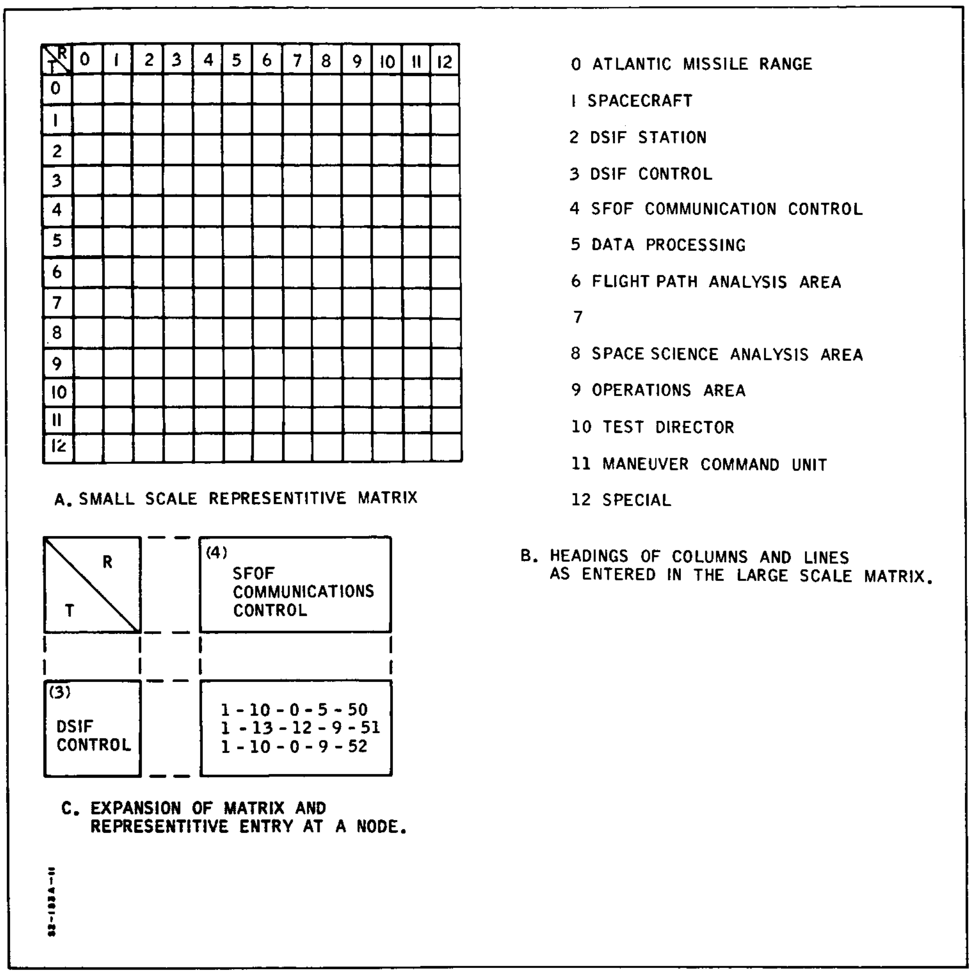

Figure B.5-1 Matrix, Quantitative Analysis Model

TABLE B-5-1. GRID ENTRY CODING

No.	Position 1 Information Class	Position 2 Signal Type	Position 3 Data Rate &/ or Bandwidth	Position 4 Time Slot
0	General Operational Data	RF Carrier with PCM/PSK/ PM Mod.	Unknown Bit Rate	Pre-Launch (exact time undefined)
1	Status (Condition and Use)	RF Carrier with PAM/ PM Mod.	60 wpm, or equivalent 30 bps	6-12 Hours before Launch
2	Spacecraft Video Data	Video Modulation	100 wpm, or equivalent 50 bps	Immediately Prior to Launch
3	Scientific Telemetry	Composite Video	1-100 bps	Immediately Post Launch
4	Engineering Telemetry	Spacecraft TV Video	1200 bps	Every 20 minutes for 1st 24 Hours After Launch
5	Command Data	TTY	2500 bps	Post-Launch (exact time undefined)
6	Flight Path &/ or Tracking	Data-Phone	20-10,000	Operations Time (undefined, or as required)
7	Timing	Microwave with S/C TV Video Mod.	± 60 cps	Pre-Operations
8	General Data-Processing Use	Microwave modulated with TTY, Data-phone, & 100 kc Data Band	5 kcs	-----------
9	General Administrative Data	Microwave with TTY Mod.	100 Kcs	Time Slot Undefined
10	-----------	Digital	2 to 3.5 mcs.	------------
11	-----------	Analog	5 to 6 Mcs.	------------

TABLE B-5-1. GRID ENTRY CODING (Continued)

No.	Position 1 Information Class	Position 2 Signal Type	Position 3 Data Rate &/ or Bandwidth	Position 4 Time Slot
12	-----------	Voice: Phone &/or Direct	Not Applicable (as in Hand-carry, hard-copy, voice, visual, mail, . .)	-----------
13	-----------	Visual: CC TV &/ or Direct	-----------	-----------
14	-----------	Telemetry (PCM/PSK)	-----------	-----------
15	-----------	Hand*Carry &/or Hard-Copy (as mail, magnetic tape, paper tape, station logs, microfilm, . .)	-----------	-----------

Note 1: The positions of a coded entry are counted from the Left.

Note 2: The coded grid entry presently used carries a Fifth Position. This is keyed to the card-index file which carries detail info. Card-Indexing is covered in Table B-5-1.

A final card file would have the detail information strictly organized. This was not done at present.

The indexing used in the present file is adequately described under Table B-5-3.

A possible improvement for retrieval might be noted. The indexing used at present could be directly adapted to a simple "Keysort" system. The sender might be punched into one side of the card; and the receiver into the other side. And, the card number might be punched into the top. This would enable four modes of retrieval: (1) by sender; (2) by receiver; (3) by receiver-sender block; and (4) by card number. A further possibility would be to use large "Keysort" cards; and, to punch the entire code in the periphery, in addition to the above.

CODE CRITERIA

The specific codes used in making entries into the grid are indicated in Table B-5-1. The basic criterion used in defining the present codes was the availability of information. (See references)

Ideally, the information to be coded and the specific coding should be tailored to the intended use of the Grid. For instance, a communications design midht have little need for an Information Class coding. However, this bit of information is very necessary in determining communication requirements - where they are not specified. As another example, the administrative manager of a system is not likely to need a great amount of detailing in the codes for signal type or bandwidth.

In the present instance, not much tailoring was possible. Sufficient information was not yet available to properly detail the coded categories. Much of the needed information will develop in the iteration of the Grid with advice from the potential user. Appropriateness of the selected categories will also be determined by iteration and user feedback.

The categories presently selected for describing the transmissions are indicated in the afore-mentioned Table; and they are: Information Class, Signal Type, Data Rate (&/or Bandwidth), and Time Slot. The specific codes used for these categories will be discussed in turn.

Information Class

The present code is the first step in establishing the informational content of a transmission. For some purposes, the broad Information Class may be sufficient description of the content. Whether or not his is true for the present purpose remains to be determined. (The present degree of detail used in the grid code certainly does not allow any operational analysis). The ultimate aim in defining the classes is conciseness of coding and completeness of coverage within the context of the problem.

The selection of the categories for this first step was based on the decision to keep the coding down to a single digit. Use of the coding may indicate the desirability of change; or, of expansion to more digits.

Signal Type

The signal types used in the coding were based, principally, on those used in Reference 5. They may prove inadequate upon running through an analysis.

In any case, the signal types listed in the Table are certainly not the ultimate in conciseness or clarity. There is some confusion in classes of signal - carrier, modulation, implementation. And, there seems to be some redundancy. However, until specification of hardware begins, this type of classification will serve.

Data Rate and/or Bandwidth

As with the previous code, the items in this coding are, in the main, those of Reference 5. Where the information was available, corrections were applied.

The heterogeneity of the bases for measuring quantity of data indicates a great lack of information. For instance, with the present code, quantity is measured in terms of (1) bandwidth; (2) bit rate; and (3) word rate. From an informational point of view, a single basis would be desireable.

Time Slot

This coding will try to define the important time slots for the transmissions. The most useful way of doing this is to define the time relative to a critical event, such as launch. Of course, there are other critical events (such as Mid-Course Maneuver) around which a time scale might be framed. Also, the time scale might be framed about a combination of critical events; such as, launch, mid-course maneuver, landing, etc....

The time scale factor was conspicuously absent in the available cataloging of information. The coding used now indicates all of the data available from a first look (N.B. More information is available now.) However, it is hoped that even the present gross scale might indicate the need for such data.

A possibly useful separation to apply in the future is that of real-time versus non-real-time. (Perhaps, in the form of separate Grids.)

TABLE B-5-2

ABRIDGED CARD FILE

Card No. | Content

10 FROM - 1 - - 0 TO

Test Director to AMR:

0-15-12-7 Space Flight Operations Plan (SFOP):
- a specialized version containing only pertinent portions will probably be desireable

- Bound Hard-Copy

- Mailed prior to operations

10 FROM - - 2 - - 0 TO

Test Director to AMR:

0-5-1-0 Alterations to the SFOP which may be required by non-standard Conditions:

- TTY at present capability of 60 wpm/30 bps.

- (Note: Where the required alteration is minor, or non-critical, voice contact by phone may be adequate.)

Card No.	Content

4 FROM - - 70 - 5 - TO

SFOF Communications (Control) to Data-Processing (Control):

From DSIF Station:
Separated, digitized, formatted Spacecraft/Station Data:

0	General Operational Data
1	AND Station Status (Condition and Utilization)
3 5-1	AND Scientific Telemetry
4- 6-4-5	AND Engineering Telemetry
5 10-9	AND Command Playback
6	AND Doppler and Angle Data
7	AND Telemetry Time Tag

- TTY with present capability of 60 wpm/30 bps. (future capability of 100 wpm)

AND/OR
Dataphone, capable of 1200 bps on a 5 kc voice-line.
AND/OR
Digital input from 100 kc Data-Band (about 2500 bps)

(Note: Real-time operation, over all phases, might require a bit rate somewhat greater than 5,000 bps.)

4 FROM - - 71 - 5 - TO

SFOF Communications (Control) to Data-Processing (Control):

$0-{10-1 \atop 12-12}-6$ Identification of poor Format Data:

- Input by Remote I/O Module probably

OR
Verbal, phone, identification may be sufficient

4 FROM - - 72 - 5 - TO

SFOF Communications (Control) to Data-Processing (Control):

8-10-1-9 Program Inputs:

The needs for inputting are very minimal as the Communications Control position. Inputs to the Status program are probably all that will really be needed. The Remote I/O Module should be adequate to take care of this need.

- Digital 60 wpm/30 bps) from Remote I/O Module

Card No.

4 FROM - - 73 - - TO 5

SFOF Communications (Control) to Data-Processing (Control):

8-10-1-9 General Data-Processing Requests:
(includes such as request for transferral of status display information)

- Digital (60 wpm/30 bps) from Remote I/0 Module

4 FROM - - 74 - - TO 5

SFOF Communications (Control) to Data-Processing (Control):

9-5-1-9 General Administrative Data required for System Operation:
- this is the administrative data originating at the DSIF stations

- input will probably be by TTY with present capability of 60 wpm. (future capability of some 100 wpm)

4 FROM - - 98 - - TO 6

SFOF Communications (Control) to FPAA:

6-5-1-3 Nominal Trajectory Data - initial Conditions (relayed directly from AMR input)

- TTY (60 wpm, equiv of 30 bps)

4 FROM - - 99 - - TO 6

SFOF Communications (Control) to FPAA:

6-5-1-5 Raw Tracking Data
(routed on request or when processing breaks down)

-TTY, with present capability of 60 wpm/30 bps (future capability of TTY may be 100 wpm)

(Note: Real-time tracking data rate is about 50 bps for azimuth and 50 bps for elevation.)

Card No.

4 FROM - - 134 - 8 - TO

SFOF Communications (Control) to SSAA:

2-4-11-5 Spacecraft TV Video Data

- Raw signal is fed to the TV Monitors in the Video Analysis Room

- Raw signal also goes to TV Processing which has film output

  - Video Signal (about 5 mcs)

4 FROM - - 135 - 8 - TO

SFOF Communications (Control) to SSAA:

3-15-12-5 Raw Analog Data:

- Hard Copy of Analog Display (future needs may call for direct analog display at SSAA)

(Notes: Capability may be needed during test operations. The required Telemetry recovery and separation is considered to be part of Communications.)

4 FROM - - 136 - 8 - TO

SFOF Communications (Control) to SSAA:

3-5-1-5 Raw Scientific Telemetry - Back-up Transmission:

- TTY, with present capability of 60wpm/30bps. (future capability of TTY will be 100 wpm)

(Note: A single line yields only about half of the minimum requirements for real-time operation.)

4 FROM - - 178 - 10 - TO

SFOF Communications (Control) to Test Director:

0-13-12-2 Information from Pre-Injection Events Display:

- Spacecraft Conditions relayed from AMR: telemetry sync., transponder freqs., etc. ...

- Visual, direct from Mission Status Board

Card No.

4
FROM - - 179 - 10
- TO

SFOF Communications (Control) to Test Director:

1-13-12-2 Countdown Status (from AMR):

Visual, direct from Display on Mission Status Board

4
FROM - - 180 - 10
- TO

SFOF Communications (Control) to Test Director:

1-13-12-5 Utilization of Each Communication Line:
-Tracking, Telemetry, or Administrative Data
-Administrative or Operational Voice Traffic

- Visual, direct from Communications System Status Display on Mission Status Board

4
FROM - - 181 - 10
- TO

SFOF Communications (Control) to Test Director:

1-13-12-6 Operational State of Each Communication Line:
- In, Out, Marginal

- Visual, direct from Communication System Status Display on Mission Status Board.

(Note: May also be required prior to operations)

10
FROM - - 203 - 12
- TO

Test Director to Gallery &/or Public Information:

0-13-12-9 General view of operations at the SFOF:

- Primarily consists of Closed-Circuit TV view (probably edited) of Mission Status Board.
(see Operations Area - internal)

- May offer view of any one of the technical areas through the Closed-Circuit TV system (with probable editing by the Test Director)

TABLE B-5-3. CODING FOR MATRIX NODES

No.	Sender/Receiver
0	AMR - Launch Site
1	Spacecraft
2	DSIF Station
3	DSIF Control
4	SFOF Communications (Control)
5	Data-Processing (Control)
6	FPAA - Flight Path Analysis Area
7	SPAA - Spacecraft Performance Analysis Area
8	SSAA - Space Science Analysis Area
9	Operations Area
10	Test Director
11	Maneuver Command Unit
12	Special

Note on Use in Indexing Card-File:

A simple consecutive numbering system is used for filing the cards. Each card is marked with a number as its code is entered in the Grid. The number will be found in the upper-central portion of the card. The number is also entered in the 5th position of the coded grid entry. This enables simple retrieval of an individual entry. This consecutive numbering constitutes the main filing system.

However, it will also be desireable to retrieve the card information by nodes. Hence, the code of Table B-5-3 is used as a supplementary card indicator. The code for the sender will be found in the upper-left corner of the card. And, the code for the receiver will be found in the upper-right hand corner of the detail-information card.

JPL-SFOF COMMUNICATIONS STUDY-PHASE I FINAL REPORT

APPENDIX B, PART 6

MATRIX ANALYSIS MODEL OUTLINE

1.0 INTRODUCTION

1.1 Include very brief description of approach

1.2 Run-down on intent and structure of paper

2.0 HISTORICAL EVOLUTION

2.1 SFOF Problem - communications requirements

2.2 Data Collection

2.2.1 Existing Condition of Data
2.2.2 Need for Organizing Collection
2.2.3 Resulting Elemental Grid

2.3 Immediate Implications - with bridge to body of paper

3.0 THE GENERAL CONCEPT

3.1 Basic Function

3.2 Structural Description

3.2.1 Grid (or Matrix)
senders/receivers as rows/columns
coded entry
associated code book or table
N. B. use small grid for description purposes

3.2.2 Card File
Cards
Indexing for Retrieval - simple tab to "Keysort" to "Magnacard"

3.2.3 Indication of Inter-dependence

3.3 How used - general sense (specific to be covered in present model)

3.4 Node Selection

3.4.1 Sources, Sinks, and Relays of Info Flow Network

3.4.2 Tailoring for specific application
egs. - terminal eqpt and terminations for comm. rqts.

3.5 Coding for the Grid Entry

3.5.1 Basic Criteria

Pertinence and Completeness

Conciseness (balanced against completeness)

3.5.2 Selection of Referents

Possible areas of coverage

Information

Message Structure

Operational/Procedural

Nodes Involved

Time Frames

Examples of Possible Referents

CONTENT
- type of information
- required detail determined by application

OBJECT
- what, or who, is it about?

VALIDITY
- how sure that information is correct?

CRITICALITY and/or PRIORITY
- how important to accomplishment of mission?

PERISHABILITY
- how long is the information valid?

INFORMATION QUANTITY or RATE
- in terms of bit-rate, work-rate, bandwidth, etc.

SIGNAL TYPE
- mode of transmission; as carrier and modulation, or communication link - choice depends on problem
- for some uses, may be broken into two separate referents

CONDITION OF DATA
- as: raw, formatted, digitized, processed, etc.

STORAGE REQUIREMENT
- how long should the reception be retained?
- closely allied to "perishability"

PRESENTATION MEDIA
- how is the transmission presented to the receiver?
- as: public address, phone, personal voice, alpha-numeric dynamic, alpha-numeric hard-copy, graphic dynamic, graphic hard-copy, etc.

ACTION
- what action is to be taken by the receiver?
- as: sink, relay, process, add and relay, store, etc.

ORIGINATOR
- where was information first originated, or developed?

SENDER
- sender of this transmission
- evident from grid co-ordinates, but may be useful with extensive grid

RECEIVER
- receiver of this transmission
- evident from grid co-ordinates; but, may be useful with extensive grid

DESTINATION
- who is the final sink for the information?
ORIGINATION TIME
- when was information first developed?
TRANSACTION TIME
- when is this transaction taking place?
MISSION SENSITIVITY
- what referents are affected by having different missions? how are they affected?
Final selection of Referents to be used
initial - guess, keeping criteria in mind
iteration thru analysis and user feedback indicates if guess is right;and, whether others may be more useful

3.5.3 Code, and measure, for the Referent
Goal - to measure the referent; but, to only as fine a grain as necessary (basic criteria)
Initial selection - likely to be limited by availability of data
Development - through use iteration
use develops more data
use and analysis decide pertinency to particular application
Notes
some referents suitable for numerical unit of measure
- as, Information Quantity
others more suited for descriptive "measure"
- as, Presentation Media

3.5.4 Relation to Card File
Need for conciseness on grid entry means that coded entry cannot and should not describe the transmission <u>completely</u>.
unused description relegated to a card file
grid entry will have to carry an extra position, or some other means, to enable retrieval of applicable card.
Special Case - where intended that computer will do the analysis
- some applications may allow putting entire description in code.

3.6 The Card File

3.6.1 Reasons card file required (see 3.5.4)
Coding conciseness
Unusual situation, or application

3.6.2 Indexing Parameters
code position for keying to grid entry on individual basis
on basis of retrieval requirements determined by specific application
One extreme - one, - the keying position of (3.6.2)
Other extreme - indexed by <u>all</u> positions (referents) of coded entry
mechanical limitations may require using only <u>selection</u> from grid entry referents.

3.6.3 Body Content

dependence on grid-entry referents and code
a minimum body content would result from maximum code, in some cases, this might result in over-complex code
Decision, or compromise, must be made on: what is immediately pertinent versus what is auxiliary information?
auxiliary information goes to card
organization for efficient use
by paragraph, indentation, line, numbering, etc.
so that entry for a particular position on card is of same category on all cards of file.

3.7 Applications Potential

3.7.1 Brief Summary of General Concept

3.7.2 Discussion of Possible Potential

Design/Analysis Tool - organization of raw body of collected data
means for presenting information to system designers
- keeps entire problem in front of designer
"Gestalt" view may give analyst and designer better "feel" for the problem.
may serve to make use of "intuition" resulting from experience
full computerization, normally
- operations are relatively hidden
- full use of experience cannot be made
computerization, with grid evaluation model
- disadvantages of full computerization overcome
Gross Inadequacies may be made more visible
- particularly on a coarse-grain grid
Information/Message Flow Chart
essentially a more numerical and specific detail flow diagram
useful as a tool for system manager, as well as for the designer - to assure proper loading
Customer/Designer meeting ground
facilitates agreement between customer and designer
- for both system requirements and system design
ideal for feedback by furnishing convenient and organized form for making notes and corrections to the rqts., et al...

4.0 <u>THE SPECIFIC MODEL</u>

4.1 The Problem - SFOF Communications Requirements

4.2 Description of Model developed

4.2.1 Grid - or Matrix

senders/receivers
coded entry
referents
code book

4.2.2 Card File
Indexing/Retrieval
needs
retrieval code
mechanical implementation
Body Content
grid code
explanation of alternatives
auxiliary information
The Physical Cards (accompanying material)

4.3 How Used

4.3.1 Generally

4.3.2 Transactions at specific sender/receiver node

4.3.3 Receiver loading

4.3.4 Transmitter loading

4.3.5 Requirements for specific type message, or information

4.4 Criteria

- short general statement or introduction
- "specific criteria used in attempt to fulfill basic criteria"

4.4.1 Choosing the Referents
present selection and reasons
criteria for better selection

4.4.2 Coding for <u>Information Class</u>
definition of referent
specific criteria used presently
indication of improvement possible, or needed

4.4.3 Coding for <u>Signal Type</u>
definition of referent
present specific criteria used
inadequacies - and improvements needed

4.4.4 Coding for <u>Data Rate and/or Bandwidth</u>
definition of referent
present specific criteria used
inadequacies - and improvements needed, or possible

4.4.5 Coding for <u>Time Slot</u>
definition of referent
presently used specific criteria
inadequacies - and improvements needed, or possible

4.4.6 Retrieval for the Card File
brief recap of the present reasons for the retrieval system
and the mechanical implementation

indication of improvement possibilities for the system and the implementation

4.5 Potential

4.5.1 Relative to Communication Problem for which Model was designed
What does model show?
What more should, or could, it show?

4.5.2 Beyond the immediate Communication Problem
All the potential of the general concept (3.7)
More specifically
- Management aid or the Test Director and DSIF Director
- Possibly a better way of presenting the SFOP
(May have different arrays for different critical periods)
- General tool for operational test and design

5.0 CLOSING REMARKS

5.1 Brief Summary - structure and function

5.1.1 General Concept
5.1.2 Specific Model - directly derivable from General Concept

5.2 Areas for Future Study

5.2.1 Implicit in Potential previously indicated for the General Concept (3.7) and the Specific Model (4.5).
General Concept
Design/Analysis Tool
Information/Message Flow Chart
Customer/Designer Meeting Ground
Specific Model
Same areas as for General Concept - slanted to specific system

5.2.2 Verifying or Denying the Validity of the proposed Potential
No amount of theorizing or arguing will serve
Only way seems to be to apply concept to a specific system yields Empirical evidence
SFOF Communication system might serve as such a vehicle
- sufficiently complex for a valid test

APPENDIX C

DETERMINATION OF COMMUNICATION REQUIREMENTS
(As of 28 June, 1962)

1.0 INTRODUCTION

This report presents a compilation of preliminary communication requirements for the various functional areas comprising the projected SFOF complex. Final detailed determination of communication needs and the equipment required to fulfill the exigencies of each operational position must necessarily await the finalization of work now in process by J. A. Hanson of HAC's Command Systems Application section and by the General Electric Display System study team. In the interim, however, this memorandum will serve to record the writer's initial understanding of JPL's present concept of the 1963 version of the SFOF communication system.

Background information for this paper has been obtained primarily from the JPL documents referenced in Enclosure 1, and to some extent from a series of preliminary conferences with representatives of the SFOF Design Team. It is the writer's intent to describe accurately the 1963 SFOF communications as presently viewed by JPL personnel, with a minimum of editorializing and extrapolation. Once concurrence has been achieved in this area, HAC review and preliminary design can proceed with reasonable assurance of being properly oriented and directed.

2.0 COMMUNICATION REQUIREMENTS

Reference to Figure C-1 will clarify some of the terminology employed in the listing of the voice communication needs to follow. Briefly, requirements for information exchange by voice within the SFOF appear to divide naturally into two more or less independent major networks, an Operational network and an Administrative network. The Operational network involves the main operational areas concerned with pre-flight testing and simulation, actual flight monitoring and control, and post-flight analysis tasks. It can be logically subdivided into three functional components: a test and simulation telephone network, an actual operations telephone network, and a voice intercom network. In practice, certain operational areas would normally be connected to these or appropriate subdivisions of these networks on a more or less permanent basis, whereas others would be connected only as the occasion demanded.

In a similar manner, the Administrative network involves those areas in the administrative and VIP category. This network, likewise, incorporates three sub-nets: an administrative telephone network, a public information telephone network, and a corresponding voice intercom network for on-lab VIP's and public information.

In addition, some of the larger, more dispersed operational areas are indicated to have their own independent telephone and voice intercom networks to facilitate the local coordination and direction required to discharge their own individual responsibilities.

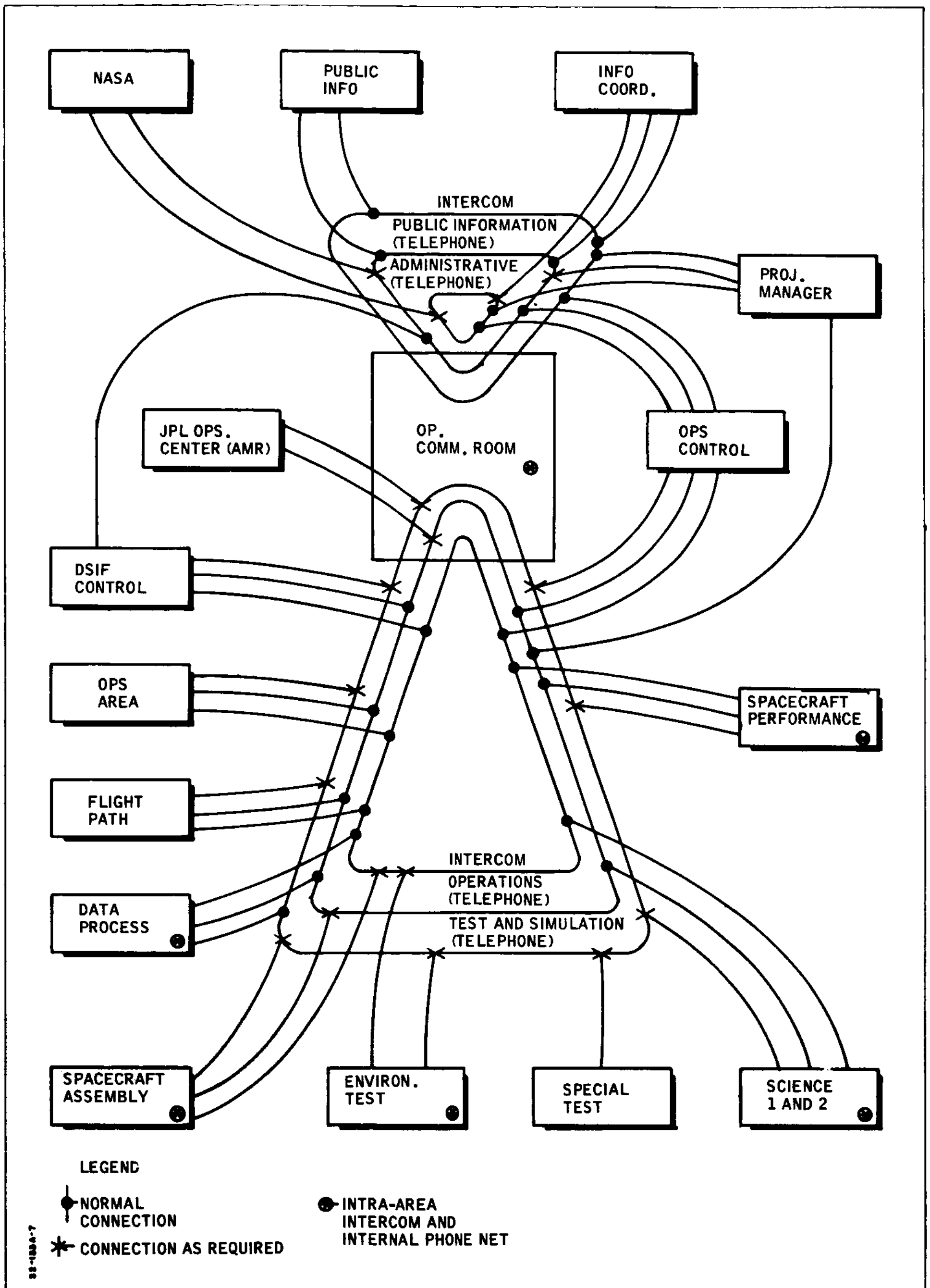

Figure C-1 Internal Voice Communications in the JPL-SFOF

In general, the networks shown in Figure C-1 will actually contain a number of semi-independent loops and sub-loops pre-patched in accordance with the requirements of each individual mission. Access to these various nets will be selective with restrictions that are not indicated here. Figure C-1 also does not indicate the commercial common-carrier telephone service available in each area, nor does it attempt to show any of the data communications which represent the vast majority of the information exchange in a typical operation.

Data and television requirements are listed as appropriate to each area. In some cases, presentation of data to a particular user will involve equipment which will clearly fall into the "display" category and be the clear responsibility of the Display team. In other cases, "display" may merely be a hard copy printout via conventional communication-type printers and thus be a Communication responsibility. In addition, there will surely exist indeterminate situations wherein responsibility assignment is by arbitrary executive decision. No differentiation in this matter is intended here.

3.0 COMMUNICATION NEEDS BY AREA

3.1 OPERATIONS CONTROL AREA

Equipment:

Two triple-station Mission Consoles, each with

Communication module,
Status display module,
Closed-circuit TV system module, and
Remote Data Processing input unit at Test Director station only

Facilities:

Data

Display of selected status information
Status entry to Data Processing system
Command generation and control
Data Processing priority control

Television

Intercom (monitor)

Operational control, all areas

Voice

Local commercial phone
Internal phone nets

Operations
Test and Simulation
Administrative
Public Information

(All areas, selective)

Intercom

Operations
Administrative

(All areas, selective)

3.2 DSIF CONTROL AREA

Equipment:

Three single-station DSIF Control Consoles, each with

Closed-circuit TV system module,
Communications module, and
Status Display module

One separate console with remote Data Processing input unit

Facilities:

Data

Status entry to Data Processing system
Display of selected status information
Microwave - Monitor and Operational control of microwave link to Goldstone
Hi-speed - Monitor and Operational control of hi-speed data links to AMR and others
TTY - Monitor and Operational control of lines to DSIF's

Television

2 monitors per console (each can view any one of 8 raw-data TTY lines from DSIF's)

Operational Control

Monitor main status board

Operational control

Intercom (camera)

Voice

1 commercial line to South Africa
1 SCAMA line to Woomera
2 leased lines to Goldstone

Operational control

Local commercial phone
Internal phone nets

Operations
Test and Simulation

(All areas, selective, except Data Processing and Communications)

Intercom

Operations

All areas, selective

3.3 COMMUNICATIONS AREA

Equipment:

One dual-station Communications Control Console with

Communications module,
Status display module,
Remote Data Processing input unit, and
Closed-circuit TV system module

Raw data storage

Video
Voice
Data

TTY

TV cameras monitoring input from DSIF's

Terminal equipment as required

Patching and switching equipment as required

Facilities:

Data

TTY - Monitor and Technical control of raw data lines to DSIF's
Hi-speed - Monitor and Technical control of Hi-speed data link to AMR and others
Microwave - Monitor and Technical control of microwave link to Goldstone
Display of selected status information
Raw data storage facility
Status entry to Data Processing system

Television

Monitor main status board

Operational control

Intercom (camera)

(Technical control, all circuits)

Voice

Local technical control of lines to DSIF's
Technical and Operational control of all other non-commercial lines
Local commercial phone
Internal phone nets

Technical control of all nets
Intra-Communications Area and support areas
Operations
Test and Simulation
Administrative
Public Information

(All areas, selective)

Intercom

Technical control of all nets
Operations
Intra-Communications Area
Administrative

(All areas, selective)

3.4 MAIN DATA PROCESSING AREA

Equipment:

One quintuple-station Data Processing System Control Console with

Communication module,
Status display module,
Remote Data Processing input unit, and
Closed-circuit TV system module

Data Processor and Storage

Facilities:

Data

Input

Raw data

TTY
Hi-speed
Video
Console status and information requests

Output

Raw data

Demultiplexed and formatted

Processed data

Status
Tracking
Telemetry
Video

Commands

Operational control of selected Data Processing units
Status entry to Data Processing system

Television

Monitor main status board

Operational control

Intercom (camera)

Voice

Local commercial phone
Internal phone nets

Intra-Data Processing and support areas
Operations
Test and Simulation

(All areas, selective)

Intercom

Operations
Intra-Data Processing

(All areas, selective)

3.5 OPERATIONS AREA

Equipment:

One quadruple-station. Operations Console with

Communication module,
Data display module,
Remote Data Processing input unit, and
Closed-circuit TV system module

Mission Status Board

TV monitor cameras

Printers and plotters } as required
Specialized equipment } as required

Facilities:

Data

Control of specialized equipment

Engineering Telemetry
Science Telemetry
Video
Tracking
} display of selected processed data available on demand

Voice

Local commercial phone
Internal phone nets

Operations
Test and Simulation

(All areas, selective, except Data Processing & Communications)

Intercom

Operations

(All areas, selective)

3.6 FLIGHT PATH ANALYSIS AREA

Equipment:

One dual-station Information console with

Communication module,
Status display module, and
Remote Data Processing input unit
Printers and Plotters as required

Facilities:

Data

Raw tracking data
Processed tracking data
Acquisition and prediction information
Display of selected status information

DSIF reports

Command request
Status entry to Data Processing system

Television

Monitor main status board

Operational control

Intercom (camera)

Voice

Local commercial phone
Internal phone nets
Operations
Test and Simulation

(All areas, selective, except Data Processing & Communications)

Intercom

Operations

(All areas, selective)

3.7 SPACECRAFT PERFORMANCE ANALYSIS AREA

Equipment:

One dual-station Information Console with

Communication module,
Status display module, and
Remote Data Processing input unit

Printers and Plotters as required

Facilities:

Data

TTY-Raw engineering telemetry
Processed engineering telemetry
Command request
Display of selected status information
Status entry to Data Processing system

Television

Monitor main status board

Operational control

Intercom (camera)

Voice

Local commercial phone
Internal phone nets

Operations
Test and Simulation

(All areas - selective, except Data Processing and Communications)

Intercom

Operations

(All areas, selective)

3.8 SCIENCE OPERATIONS BOARD ROOM

Equipment:

One dual-station Information Console with

Communications module,
Status display module, and
Remote Data Processing input unit.

Facilities:

Data

Display of selected status information
Processed Science telemetry
TTY - patch panel access to raw data
Processed video data
Status entry to Data Processing system

Voice

Local commercial phone
Internal phone nets

Intra-Space Science
Operations
Test and Simulation

(All areas, selective, except Data Processing and Communications)

Intercom

Intra-Space Science
Operations

(All areas, selective)

3.9 SPACE SCIENCE ANALYSIS AREA NO. 1

Equipment:

Printers and Plotters as required
Video display

Facilities:

Data

TTY - patch panel access to raw Science telemetry
Processed video data
Processed science telemetry
Command request

Television

Monitor main status board

Operational control

Intercom (camera)

Voice

Local commercial phone
Internal phone nets

Intra-Space Science
Operations
Test and Simulation

(All areas, selective, except Data Processing and Communications)

Intercom

Intra-Space Science
Operations

(All areas, selective)

3.10 PHOTO PROCESSING ROOM

Facilities:

Voice

Local commercial phone
Internal phone nets

Intra-Space Science
Operations

(All areas, selective, except Data Processing and Communications)

Intercom

Intra-Space Science
Operations

(All areas, selective)

3.11 VIDEO ANALYSIS ROOM

Equipment:

Video display

Facilities:

Data

Processed video data
Command request

Television

Monitor main status board

Operational control

Intercom (camera)

Voice

Local commercial phone
Internal phone nets

Intra-Space Science
Operations
Test and Simulation

(All areas, selective, except Data Processing and Communications)

Intercom

Intra-Space Science
Operations

(All areas, selective)

3.12 SPACECRAFT ASSEMBLY AREA

Facilities:

Data

Simulated real-time data to Data Processing system

Processed simulated data back

Voice

Local commercial phone
Leased lines to Cape available for patch
Internal phone nets

Operations
Test and Simulation } as required
Intra-SAF

(All areas, selective, except Data Processing and Communications)

Intercom

Operations
Intra-SAF

(All areas, selective)

3.13 ENVIRONMENTAL TEST AREA

Facilities:

Data

Simulated real-time data to Data Processing System

Processed simulated data back

Voice

Local commercial phone
Internal phone nets

Test and Simulation (as required)
Intra-ETF

(All areas, selective, except Data Processing and Communications)

Intercom

Operations
Intra-ETF

(All areas, selective)

4.0 SFOF REFERENCE DOCUMENTS

TITLE	DATE	IDENTIFICATION
Space Flight Operations Facility Design Criteria	2 Feb. 1962	EPD-68
Space Flight Operations Complex Design Preliminary Design Report	23 March 1962	DMJM, SPR 62-1

TITLE	DATE	IDENTIFICATION
Space Flight Operations Plan Mariner R, Missions P-37 & P-38	30 April 1962	EPD-82
Space Flight Operations Facility Data Processing System Preliminary Design Report	25 May 1962	372.10/70
Composition, Function & Utilization of Consoles in the SFOF	28 May 1962	TM 316-9
Science Requirements for Internal SFOF Communications	31 May 1962	IOM from S. Z. Gunter to J. P. McClure

5.0 SFOF CONFERENCE NOTES

As a preliminary step in the process of getting on board in the SFOF (Space Flight Operations Facility) communications problems area in learning the present thinking of JPL personnel relative to SFOF operations, HAC personnel have participated in a series of short informal conferences with representatives of the various operational groups comprising the SFOF organization. These conferences served three purposes:

To establish an initial contact between JPL and Hughes personnel and to promote a mutual understanding of our respective functional responsibilities.

To discuss, on a preliminary level, specific communication needs and desires in the proposed SFOF, and

To encourage all concerned to give further and more critical consideration to communication requirements in the immediate and more remote future.

During the course of the conferences, the following people were contacted:

Name	Area of Interest
P. J. Rygh	Test Director (Lunar)
T. S. Bilbo	Test Director (Mariner R)
C. W. Johnson	DSIF Telecommunications
A. N. Henke	Systems Organization and Design Book
J. F. McGee	Spacecraft Assembly Facility
T. W. Hamilton	Orbit Determination
L. M. Bronstein	Engineering Telemetry (Spacecraft Performance)
A. Arcand	Computer and Data Processing
R. Nathan	Space Science
J. H. Morecroft	Space Science

Name	Area of Interest
S. Z. Gunter	Space Science
P. A. Tardani	DSIF Operations Manager
M. S. Johnson	Test Director
J. P. McClure	Communications

Attached are notes taken by the writer (Mr. J. W. Gibson) during these preliminary conferences. In all cases, the writer and E. G. Williamson were in attendance, representing HAC. In a few instances, HAC personnel J. A. Hanson, H. J. Price, and R. J. Rieder were also present.

5.1 CONFERENCE WITH P. J. RYGH, TEST DIRECTOR (LUNAR) 22 MAY 1962.

Mr. Rygh presented an interesting account of the initial phases of a typical shot together with valuable background information on general SFOF operations during a typical flight.

The Project Manager is in charge at AMR during the launch and injection phases of a space shot. After the injection, he flys to JPL to assume overall responsibility for the remainder of the flight.

Communications-wise, critical phases of the flight are as follows:

Launch and Injection phase - Tracking and engineering telemetry data are essential during a minimum period of approximately four hours.

Premaneuver phase - Engineering telemetry data is important.

Maneuver phase - Command data is critical.

Postmaneuver phase - Engineering telemetry and tracking data indicate the response of the vehicle to command.

Internal communications of particular utility to the Test Director are two headset nets. One is a status net, used during the prelaunch phase for prelaunch status, and after launch for postlaunch status purposes. The second is a voice net for coordination purposes to facilitate overall SFOF operations and commands. A third net utilizing telephone call-director facilities has been used in the past, but Mr. Rygh personally is not too happy with its operation.

5.2 CONFERENCE WITH T. S. BILBO, TEST DIRECTOR (MARINER R) 22 MAY 1962

One of the weak points in present operations is the necessity for data conversion and voice communication coordination to permit the entry of telemetry data into the data processing system. A real need exists for on-line processing of telemetry data to eliminate these steps.

A high-speed (70 bits per second) telemetry link between JPL and Goldstone is operational for the forthcoming Mariner shot. With the completion of the microwave link, it is planned to increase the Mariner data rate to 10,000 bits per second while the spacecraft is near the earth. This bit rate would have to be reduced to approximately 100 bits per second at the ranges of the target planets.

One of the major objectives of internal communications should be an attempt to eliminate people operating in serial fashion. Consequently individual access to all required communications should be via pushbutton connections.

Closed-circuit TV will be used, for the first time, on the Mariner shot in July. Mr. Bilbo is presently uncertain about its utility.

A computer program to eliminate bad data points is planned, but it is not yet ready.

5.3 CONFERENCE WITH C. W. JOHNSON, TELECOMMUNICATIONS, 22 MAY 1962.

Launch tracking stations will eventually become part of DSIF operation, a 40-foot dish being scheduled for installation of AMR in 1964 for this purpose. Thus, additional data circuits will be required since no tracking data is now available, only telemetry data. At present the Agena telemetry net is monitored at L-band prior to separation of the first stage. Consequently the spacecraft, following launch, is out of communication contact with the DSIF stations for a short time, approximately 20 minutes for the Ranger series and approximately 10 minutes for the projected Mariner series. Plans for the future include X-band contact with the spacecraft following separation from the second stage.

Foreign DSIF installations are operated and maintained by foreign nationals. Funding, however, is via NASA. Funding for next year includes two additional DSIF's, one somewhere in Europe and another in Australia. These added DSIF's will increase the azimuth launch angle capability and will permit additional deep space probes to be handled simultaneously.

JPL will support PMR (Pacific Missile Range) for the ADVENT program, weather satellites, and other polar-orbiting missions. This support will be handled through DSIF No. 4 at Woomera via JPL for coordination and direction.

Telemetry and tracking data from DSIF sites will be monitored by the DSIF Operations Manager. He will have the facility to interrupt the data circuits if the data is bad. In case of trouble in overseas circuits, voice communications will be utilized to alert both ends of the circuit of trouble conditions. Troubleshooting will then be initiated from both ends of the circuit to facilitate restoration of service.

5.4 CONFERENCE WITH A. N. HENKE, SYSTEMS ORGANIZATION AND DESIGN BOOK, 22 MAY 1962.

The SFOF design book will document the overall SFOF design philosophy, listing objectives, design criteria, and constraints. It will delineate the personnel organization and their functional interrelationships. Further, the design book will present functional equipment specifications and explanation of how the equipment is to be used.

HAC contribution to the design book will fall into the latter category (functional equipment specifications, explanation of equipment operation) under the communication systems section. The HAC contribution should include a general discussion of the communications system and equipment with subsections on voice, data, and closed-circuit TV.

5.5 CONFERENCE WITH J. F. McGEE, SPACECRAFT ASSEMBLY FACILITY, 23 MAY 1962.

Present plans for spacecraft checkout include sending simulated vehicle data from the vehicle at SAF (Spacecraft Assembly Facility) to the computing area for real-time data reduction. Computer printout and plotting would be returned to SAF for check. Operation in essentially the same manner with Goldstone is proposed for checkout purposes. In this case, test data from the vehicle would be transmitted to Goldstone over the proposed microwave link. Mission simulation would be accomplished by transmitting data back over normal mission channels for checkout and training purposes. Still further in the future, vehicle checkout at Cape Canaveral will be performed by sending simulated data to JPL over normal data channels. Since AMR prefers not to transmit raw data, this simulated data would be demodulated and digitized prior to its transmission via either teletype or data link. Under such circumstances, it would be desirable to transmit the data back again to AMR for evaluation. Another possibility would be the installation of a special computer at Cape Canaveral to provide real-time data reduction for prelaunch checkout.

For Surveyor and other outside projects, JPL will provide coordination and evaluation functions only, and there will be no particular communication requirements for SAF under these conditions. (In general, lunar spacecraft will be built and checked off-lab, whereas planetary spacecraft will be on-lab responsibility.)

For the Mariner R shots, SAF personnel desire to obtain raw vehicle data via the DSIF's to permit them to perform rough checks at AMR.

5.6 CONFERENCE WITH T. W. HAMILTON, ORBIT DETERMINATION, 23 MAY 1962.

At the present time data is received at a maximum rate of approximately one point every 10 seconds. This rate is, in general, higher than is necessary for sufficient redundancy to permit the detection of errors in the data. The present thinking is, therefore, that the quantity of data should be reduced but that the quality should be increased. In other words, JPL prefers to have fewer bad points rather than more good points in the data. After approximately the first hour of a flight, one data point per minute is probably adequate.

The error rate presently experienced on data transmission facilities is approximately one in every 1000 bits according to J. P. McClure. This error rate will probably be satisfactory for operations in the near future. Typical data messages contain approximately 100 words. Error detecting and correcting techniques must be employed to assure that these messages are accurate.

The communication requirements of the Orbit Determination group in the SFOF operations are primarily between the Tracking Data Analysis personnel and the DSIF telecommunication people. Of secondary importance are conference connections with the DSIF Operations Manager and the Test Director. In addition, accurate documentation of occurrences is important. This requires that status display and, in particular, DSIF station reports be up to date and accurate.

The SFOF will provide some support to the APOLLO program. In this program, one data point is required every five minutes during the first 30 minutes of flight, and every 15 minutes for the duration of the flight. An overall time lag of five to ten minutes is acceptable.

5.7 CONFERENCE WITH L. M. BRONSTEIN, ENGINEERING TELEMETRY (SPACECRAFT PERFORMANCE), 23 MAY 1962.

From the telemetry standpoint, the data rate should be as high as possible. In the Mariner B program near real-time data is planned at a maximum rate of 5000 bits per second. This rate will reduce to approximately 21 bits per second minimum on the Mars Flight. This minimum bit rate can be increased to 300 or 400 bits per second with the 210-foot dish planned for Goldstone in January 1964. A bit rate of 600 bits per second from overseas sites should be adequate with an operational data selection system. This selection can be accomplished by card programming under control from SFOF.

Voice communication requirements include connections with the Test Director, with the DSIF control, and with all major functional areas. Some of this requirement may disappear in the future with better status display facilities available.

Critical mission time periods, from the engineering telemetry standpoint, occur immediately after injection, during orientation, and immediately prior to, during, and following maneuvers.

An error detection program is desirable to tag parity errors and gross blunders. The erroneous data points, thus tagged, need not be separated further from the main data stream since they will be ignored by the computer.

5.8 CONFERENCE WITH A. ARCAND, COMPUTERS AND DATA PROCESSING, 24 MAY 1962.

Members of the data processing group have developed plans for a central data processor utilizing an IBM 7094 as the primary computer. In conjunction with this, an IBM 7040 computer will be employed as an input-output data processor to provide demultiplexing, formatting, error detection, and distribution capabilities. Any number of inputs up to 64 can be accommodated in associated core storage and disk storage facilities at a total input and output bit rate of 100,000 bits per second. Output is to four printers, four plotters, and three monitors in accordance with a selectable priority program.

The present data processing system utilizes commercial teletype circuits for input data almost exclusively. The main problems are the separation of the incoming data into appropriate channels and the separation of the erroneous data from the valid data. Specifically mentioned was the need for the addition of parity check on tracking data, which is apparently not incorporated at the present time.

J. P. McClure has written a memorandum outlining format specifications for teletype communications. This memo details such items as word lengths, longitudinal and lateral parity, and preamble address, EOB, etc. Teletype speeds appear to be adequate for at least the near future. For maximum data rates in the Mariner program, for instance, 12 hours of real-time data can be transmitted in 16 hours at teletype speeds.

5.9 CONFERENCE WITH R. NATHAN, J. H. MORECROFT, AND S. Z. GUNTER, SPACE SCIENCE, 29 MAY 1962.

Operational organization within the Space Science areas will direct activities through a Science Operations Board to coordinate activities in Space Science Display and Analysis Areas 1 and 2, the Video Analysis room, and the Photo Processing room. There will be much voice and hardcopy communications required between these areas. Each area will have access to the commercial phone system. There will be a maximum of approximately 70 people in all Science areas.

Console operators will be trained technicians under the supervision of the Science Director, who will roam the area with headset communication facilities. There will be a single lateral phone circuit from the Science Operations Board to each Science area with communication needs. One or two conference loops will be sufficient. No video intercom facilities will be required. The capability to talk directly to Science representatives who may be stationed at DSIF locations should be provided.

In normal operation, the Test Director's only involvement in Science hierarchy activities will be on a veto basis.

Although some want raw data available, its use by scientists will be discouraged. It should be available as backup, however, and patch panel access with bridging facilities is desirable and would suffice.

Data rates of 100 bits per second are probably realistic minimums for full-scale Science operation, since sampling at twice the highest response frequency includes all available information. In general, real-time loop operation is not required. The tightest loop anticipated will accommodate delays of approximately five minutes. There will be very limited command control while the vehicle is in view of Woomera or Johannesburg. It is planned that there will be no closed-loop capability in this situation and certainly no decisions required.

Facilities to support simulated operations are mandatory.

5.10 CONFERENCE WITH P. A. TARDANI, DSIF OPERATIONS MANAGER, 29 MAY 1962.

The DSIF control room acts as the DSIF to the SFOF. Conversely the DSIF control room acts as the SFOF to the various DSIF sites. It acts as the mutual direct contact and interface between the two functions. The function of the DSIF Operations Manager is to control the operations through talkers to the DSIF stations, and to monitor all data interchanged between the SFOF and DSIF's. In case of communication problems, the DSIF Operations Manager would call in either Communications or the DSIF concerned as appropriate to remedy the situation.

Monitoring of all DSIF input data requires that the teletype tapes be examined manually. To perform this function in the SFOF, it is planned to provide three consoles in the DSIF control area to coordinate control of the three major DSIF locations. Each console will contain two closed-circuit TV monitors, each with a capability of monitoring any of eight incoming lines of data. The field of view of the TV monitor will be such as to provide approximately 15 lines of teletype history at each teletype printer. In conjunction with the monitoring of incoming data, the DSIF Operations Manager must be provided with operational control of the data lines from the DSIF's to the data processing area. The purpose here is to prevent bad data from entering the data processing system. As a back-up operation, two DSIF observers will be stationed in the Orbit Determination group to give feedback on the validity of the incoming raw data.

High speed data will not be monitored in this fashion because of the inability of the human being to keep up with the data. Similarly, video data will go directly to the Space Science area.

There will be no manual monitoring of non-real-time data. In this situation the computer program will determine whether the data is good or bad by some pre-established criteria. On this basis the bad data will be separated for review by human means and clean-up by the Data Reduction Laboratory.

5.11 CONFERENCE WITH M. S. JOHNSON, TEST DIRECTOR, 31 May 1962.

In general the Test Director will normally function in parallel, rather than serially, with other operational areas of the SFOF. Mr. Johnson believes that it is more desirable to delegate as much responsibility as possible and provide direction and coordination in the capacity of a monitor. The important exception to this is the command channel to the spacecraft in which each command or sequence of commands must be approved by the Test Director prior to transmission.

Communications will have the responsibility for raw data distribution and for data displays. These displays include high-speed printers, plotters, computer-driven CRT, and video (spacecraft TV). Communications will also be responsible for some status displays, namely communications system status. In this area positive indication of status is wanted. As an example if a lighted lamp indicates that a particular circuit is operable, another lighted lamp should indicate that the circuit is inoperable. In general, the status displays will be the responsibility of General Electric and will include some data display.

For the Mariner R program, all three DSIF's will have control facility. In fact in this program, control will be exclusively from the DSIF's. Control is exercised by means of two different types of command:

> Stored commands, transmitted to the vehicle in flight and held in storage in the vehicle for activation at a future time. Following transmission these commands are read out of the vehicle store and telemetered back to the SFOF for comparison with the command originally transmitted.
>
> Real-time commands of the start-stop type. The only verification of real-time commands is the subsequent response of the vehicle.

The design of the SFOF Communication System must provide:

1. System patch capability - mission to mission,
2. Ability to accept data over phone lines,
3. Facility to exercise maximum use of SFOF in simulation activities.

5.12 CONFERENCE WITH J. P. McCLURE - COMMUNICATIONS, 7 JUNE 1962.

Communications requirements for ETF (Environmental Test Facility) and SAF (Spacecraft Assembly Facility) will be the same, in general, as for AMR at Cape Canaveral.

The desire to send raw analog data from the Cape to JPL will be fulfilled by providing a 48 Kc Telpak group to handle the 3.3 Kc of data.

There will be no common carrier conferencing tie-in provisions within the SFOF.

The Console memo by Mr. Johnson and Mr. Tardani supercedes the DMJM report.

JPL - SFOF COMMUNICATIONS STUDY - PHASE I FINAL REPORT

APPENDIX D

PRELIMINARY SYSTEM DESIGN - FINAL REPORT

1. INTRODUCTION

Problem Definition

The future success of the United States' contribution to man's conquest of space rests in large measure with the Jet Propulation Laboratory in Pasadena which is charged by the National Aeronautics and Space Administration with the responsibility for the unmanned exploration of the moon and the planets. In order to carry out this responsibility effectively, JPL must provide the planning, the instrumentation, the personnel, and the direction to achieve a centralized capability to conduct a wide variety of space flight operations. These operations include gathering data about and from the spacecraft, processing this information and presenting it adequately to human operators for their evaluation and decisions, and transmission of the required commands to the spacecraft during the portion of flight from launch to accomplishment of the mission. The Space Flight Operations Facility must provide the capability to meet these requirements.

Design Objectives

The success of the SFOF installation will be a direct function of the degree to which the communications system is able to integrate sensors, data handling and processing services, and control functions into an effective and efficient operational system. This, in turn, is dependent upon the ability at the present time to define a realistic and adequate communication system to be operational as a Stage I design by the end of 1963, to be revised as required from operational experience into a Stage II design by the first of 1965, and to be capable of graceful evolution from there into the environment of the foreseeable future.

In addition to falling within the above time schedule, the communication system must maintain compatibility with existing and projected modes and means of communication. It must be sufficiently flexible to accommodate a great variety of missions with different objectives and operational idiosyncrasies, and at the same time it must retain a high degree of reliability over extended periods of time. The design must provide for continued improvement in procedures and equipment as experience and technical advances made further improvement feasible. On the other hand, present equipment that is functionally adequate must not be replaced without careful operational or economic justification. In short, the design must in no way inhibit concept modifications and innovations to enhance and maintain maximum over-all system effectivity.

Limitations

Adequate system design at the present is subject to two serious limitations: paucity of operational experience and shortness of time.

One of the aspects of the job that makes it so challenging is the fact that it is something that has really never been done before. Deep space missions to date have been few and have been on a scale which can only be considered primitive in comparison with those to be conducted in the near future. Operational experience gained thus far has been relatively meager and, while providing some important data, must be classified as of essentially a preliminary nature. Unfortunately, however, this is the only information available and must be utilized as the basis for logical extrapolation to future activities.

Under such circumstances it is highly desirable to conduct an extensive study of the problem, analyzing objectives, ascertaining responsibilities, reviewing past performance, and determining requirements. Since the restricted time schedule precludes such a study to the desired depth, the resultant system design must necessarily reflect these inadequacies and be subject to the limitations thereby imposed.

Conclusions

The design presented here represents a preliminary version of the optimum communication system possible within the limitations outlined above. Proven techniques are employed to achieve maximum reliability compatible with the flexibility to accommodate the scope of activity anticipated not only at the present time, but as a result of the evolution of design and operational concept that is inevitable with the accumulation of additional knowledge and experience.

2. DESIGN APPROACH

Philosophy

The philosophy permeating the design of the communication system is based upon three primary criteria: reliability, flexibility, and economy.

Reliability is a primary consideration in all aspects of system design. The choice of equipment, obviously, must be concerned with the integrity and capability of the manufacturer, his reliance on tested principles, and strict adherence to design limitations in system application. Care must be exercised that all system components are compatible in all respects and that system operating procedures are carefully considered to ensure that the available equipment complements the personnel for which it is intended as a tool.

System flexibility is closely related to system reliability in several respects. Modularity of equipment design, for instance, contributes to reliability by permitting a variety of possible system configurations and modes of operation which in turn provide the possibility of quickly activating alternative emergency backup modes. This system flexibility also contributes the ability to adapt the system to the wide variety of mission objectives and design concepts expected with the more advanced missions of the future. In addition, system flexibility provides the best assurance of continued compatibility with facilities to be added in the future to meet expanding operational requirements and commitments.

Net cost considerations are ever-present in systems design and planning. This includes not only first-cost, but continuing maintenance and replacement resulting from obsolescence. Every effort must be exercised to anticipate changing requirements in the initial selection of equipment such that it will be both compatible with existing gear and as far as possible consistent with changing emphasis for a reasonable period of time.

Assumptions

In this, as in other complex situations, the adoption of a few simplifying assumptions can materially reduce the complexity of the system, as well as its cost, and can at the same time enhance its utility and increase its reliability. The assumptions basic to this design are, essentially, that the personnel operating the system are rational and intelligent individuals, that they are mature and reliable, and that they are capable of making decisions within their own jurisdiction. The system, therefore, is not designed to be fool proof. Rather, it is designed to be a useful adjunct to the intellect and capability of its human operators. The design will encourage certain pre-established operational procedures; it will discourage others; but the basic precept is flexibility to meet changing patterns of technology, system concept, and emergency operation impossible to predict.

3. SYSTEM DESIGN

General Discussion

Actual system design is illustrated in the simplified block diagram of Figure 1. It can be seen to incorporate three generalized modes of communication: Voice, Data, and Closed-Circuit TV, all circuits of which are available on main frames in the Communication Area for patching and switching as desired. Technical control of all circuits is exercised either directly or indirectly from the Communications Control Console in the Operational Communications Area. Ordinarily, accessibility of the user stations to the various data and telephone lines is set up here prior to a particular mission, or by established procedure as emphasis changes or non-standard conditions arise during the course of the mission. Limited operational control resides in most cases with the user to permit him as wide a latitude as possible, within the above framework, in the selection of functional and supporting information.

Indication of the status of the various incoming lines, the terminal equipment, the raw data storage equipment, and the internal switching and PA equipment all will be available in the basement communication rooms

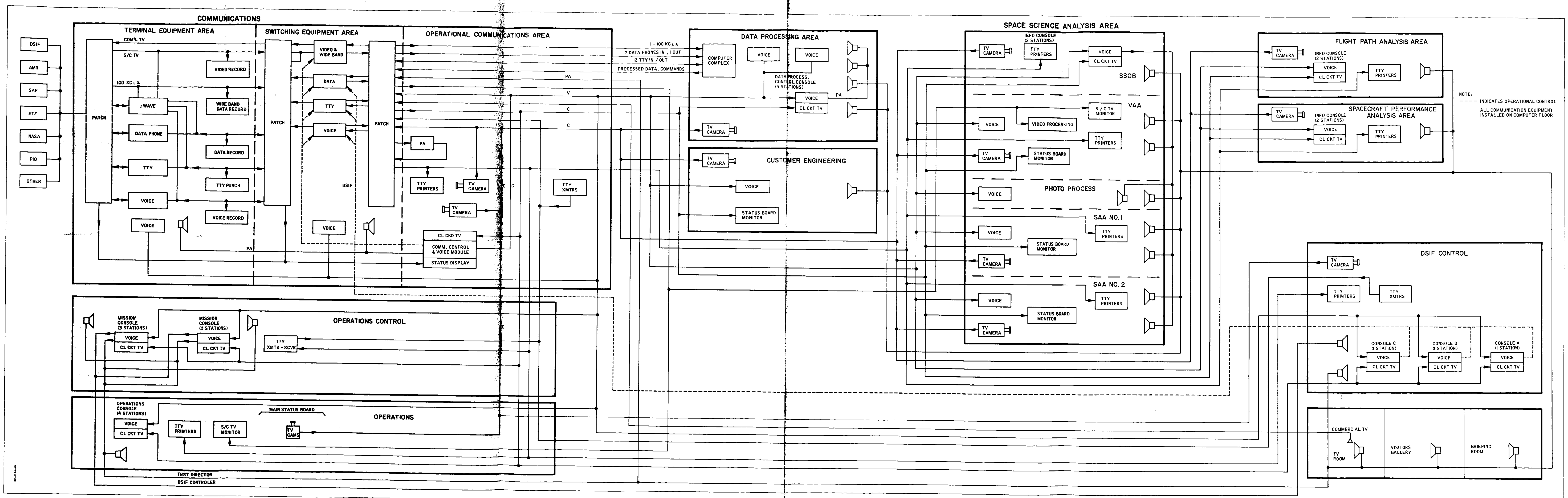

Figure D-1 SFOF – Communications Block Diagram and will be wired from there into the Operational Communications Console. Selected portions of this status information can be further disseminated from there for general display purposes within the SFOF.

Voice

Voice communications are employed for the more subjective aspects of space flight operations, such as work coordination, conference discussion of special problems, issuance and explanation of non-standard instructions, etc. Included are three subsidiary categories: intercom telephone, public address, and commercial telephone. In general, none of these will be employed to transfer quantitative data which can be handled much more efficiently and effectively by the data and display facilities.

Intercom Telephone

Telephone inter-communications within the SFOF complex will employ a machine-switching system in which every station will have, essentially, access to every other station. Isolated and independent networks, per se, will not exist. Instead, each station will have its own set of stored numbers to facilitate calls within its own "area of interest" or functional "network". In this concept:

- Each operational position will be provided a set of pushbuttons permitting direct selection of others in its own "net".
- Each operational position will be provided a dial for calling any <u>other</u> position.
- Conferencing is accomplished in either case by depressing the desired combination of buttons and/or by sequential dialing.
  - A locking pushbutton will be provided to enable the "talk" facility, with the actual transmission of speech being controlled by a voice-operated relay.

A number of stations will be assigned a "priority" level in the system. These stations include: Project Manager, Test Director, Assistant Test Director, SFOF Manager, Operational Communications, Main Data Processing, DSIF Control, FPAA, SPAA, SSOB, and Customer Engineering. Completion of a call to any station is a function of the priority status of the calling station and the use status (busy or idle) of the called station.

- Called station is signalled by both aural and visual means if idle.
- If called station is busy, calling station receives a "busy" signal but "camps-on" desired line:
  - If caller is a priority station, caller depresses his "Break-in" button to establish a conference connection with called line. Calling party has option to:

1) Interrupt if, in his judgment, his call is more urgent than the call in progress, or

2) Retire gracefully.

If caller is a non-priority station, he may depress his "Break-in" button to light the "Hot Call" light on the called station panel to indicate an urgent call. Called party has option to:

1) Complete his own conversation first, after which camp-on connection is automatically established, or

2) Allow interruption on a conference basis by depressing his own "Break-in" button.

In each case, the final judgment is exercised by the operator of a priority level phone who can be expected to have sufficient insight into and information about the over-all operation to make the decision reliably.

Public Address

The use of the Public Address facility will be minimized because of its distracting qualities and its addition to the level of general background noise. Its main utility will be for the issuance of special instructions and the dissemination of information of general interest. In special emergency situations, it may be used for paging.

Access to the common PA system is in general restricted to the Test Director for special announcements, and to the Operational Communications Area for patching as required to AMR, the Project Manager, NASA, etc. for general-interest information. In addition, certain operational areas such as DSIF, Communications, and Main Data Processing have support activities so dispersed physically as to require this means for centralized direction and coordination. In these cases, pushbutton access to their own localized PA network is provided on the voice communication modules of the respective area directors. (See Figure 2)

Commercial Telephone

Although not shown on the block diagram, all areas throughout the SFOF will be supplied with adequate telephone handsets to permit normal access to the external common-user commercial telephone system.

Data

Data communications facilities will handle all quantitative information involved in determining the flight path of the vehicle, in monitoring its behavior, and in analyzing the results of its scientific experiments. In addition, digital data will be utilized to transmit routine status reports from the DSIF installations, test and pre-flight information from SAF, BTF, and AMR, and to send command messages to the vehicle. Data thus will carry the major

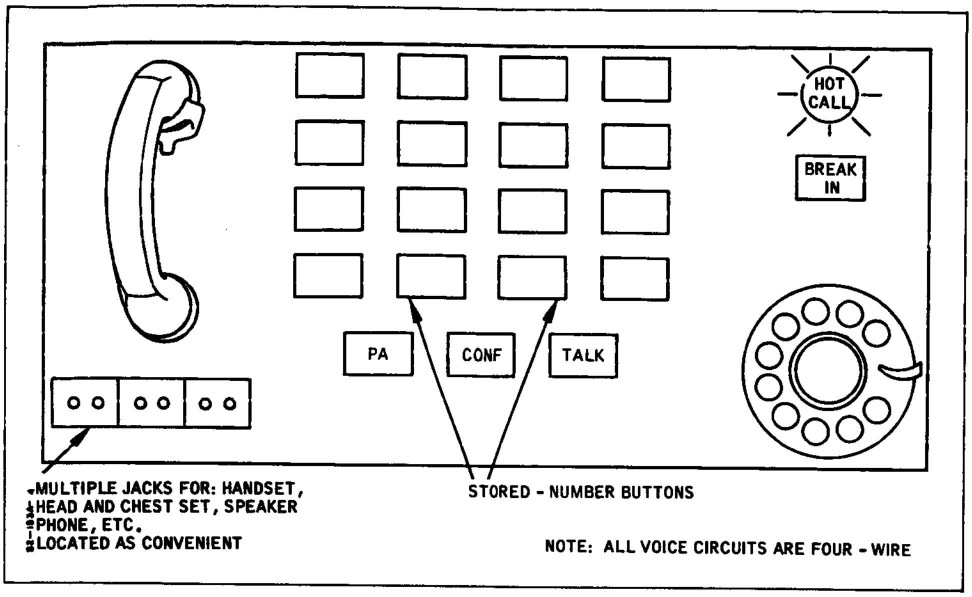

Figure D-2 Voice Module

bulk of the information transfer load into and within the SFOF; the ability to maintain its fidelity and to process and disseminate it effectively and reliably will without doubt be the biggest single factor contributing to the success of the SFOF.

Data communications fall into four categories: teletype, Data Phone, hi-speed digital, and video. As in the case of the voice circuits, all data circuits, regardless of category, will pass through the Operational Communications Area where they will be available as required for patching and switching to various users. Dissemination of raw teletype data prior to processing by the computer will be discouraged, but may be provided for operational evaluation in some instances, and must be supplied as back-up in most areas during periods of computer failure.

Teletype

Teletype is the means presently used to transfer most of the data from AMR and the remote DSIF stations to the SFOF for processing and analysis. This service is provided by common-carrier facilities at 60 words-per-minute. In all but the most critical time periods of a typical shot, this data rate is sufficient and will undoubtedly be utilized for a significant time in future operations. 100 words-per-minute and higher speed operation may become feasible later, but no significant changes in system design appear to be in order as a result.

Data Phone

Bell System Data Phone facilities are expected to be available between Pasadena and AMR in time for the activation of the SFOF in late 1963. This equipment operates at 1200 bits-per-second over a 5 kc voice line and requires no special handling other than Bell furnished terminal equipment.

Hi-speed Digital

The data processing equipment is capable of accepting input data in any combination and at any total equivalent data rate up to 100,000 bits-per-second. Usually the input channel will be composed of a relatively large number of independent data sources operating at the much lower data rates of teletype and Data Phone. It is conceivable, however, that it may be desirable to bring in data over a single channel at the 100 kilobit rate, and specially engineered circuits will be incorporated in the system design to handle this eventuality.

Video

Video data from the spacecraft may arrive in either of two forms, digital or analog. In the former case, the television signal is digitized and transmitted at varying rates from 20 bits-per-second to 10 kilobits-per-second depending upon the video signal-to-noise ratio. In the latter case, the raw analog voltage signal is transmitted in a conventional manner over channels up to 4 Mc in width. Facilities to patch, switch, and distribute both forms of video data will be incorporated into the Phase I system design.

Closed-Circuit TV

The Stage I design will include a closed-circuit TV system on an experimental basis to provide a means for the monitoring of the Main Status Board by the remote areas within the SFOF. It will also be utilized by the DSIF "talkers" to monitor data coming in by teletype from the DSIF stations. TV circuits of this type would in general be set up once in the Operation Communications Area and thereafter left unchanged. Remote control of the pickup cameras is performed by the user operators.

Provision for the incorporation of closed-circuit TV as a video intercom system will also be included in the Stage I design. Such a system would place a TV pick-up camera in a strategic location in each functional area. The camera would be remotely operated from a centralized location, probably Operations Control, or possibly Operational Communications. Facilities to distribute these pictures to any TV monitor in the SFOF by patching or switching is a relatively simple matter once operational procedures and limitations are specified.

Implementation

The communication system design is in all respects straight forward and dependent upon the present state-of-the-art. As a consequence, actual procurement and implementation is not anticipated to present any great problems. Two rather obvious and general observations, however, are appropriate at this point:

- Long lead-time items must be ordered first, and
- In cases where there is a choice, an item which will permit even partial system operation or personnel training functions to be established will be given priority installation over those items which will not.

4. Summary

A preliminary design of the communication system for the SFOF is presented here to establish a working base upon which a more detailed design can be constructed. A number of items are discussed in generalities because insufficient information to delineate them in more detail is available at this time. Certain system design and operational concepts must be crystallized and system responsibility must be further definitized in some areas before much more detailed progress is possible.

APPENDIX E - DESIGN SPECIFICATIONS - SFOF OPERATIONAL VOICE COMMUNICATIONS SYSTEM

1.0 SCOPE

1.1 Scope. It is the purpose of this specification to establish the design requirements for the operational telephone system to be installed in the Space Flight Operations Facility (SFOF) of the Jet Propulsion Laboratory (JPL) at Pasadena, California. This operational system will provide voice communications within the SFOF and will provide terminating, switching, and distribution capabilities for circuits extending beyond the SFOF.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents form a part of this specification:

SPECIFICATIONS

JPL-20025	General Specification, Contractor Quality Control Requirements
JPL-30608	Standard Specification, DSIF Assembly Identification Ground Equipment
	Standard Specification, SFOF Paint Standard
	Standard Specification, SFOF Engraving Standard
	Standard Specification, SFOF Operational Communications System Installation Standard
	Standard Specification, SFOF operational Communications System Equipment Racks.

3.0 REQUIREMENTS

3.1 Conflicting requirements. Any conflicting requirements arising between this specification and any specification or drawing listed herein shall be referred in writing to the JPL cognizant engineer for interpretation and clarification.

3.2 Requests for deviation. Any deviations from the requirements of this specification or from the drawings, specifications, publications, materials, and processes specified herein shall be considered a design change or deviation and shall not be allowed except by written authorization from JPL.

3.3 Materials, Parts, and Processes. Materials, parts, and processes used in the design, fabrication, and assembly of the product covered by this specification shall conform to the applicable documents specified herein. The contractor's selections shall assure the highest uniform quality and conditions of the product suitable for the intended use, and such selection shall be subject to the approval of JPL.

3.4 Design Objectives. The system shall be designed for optimum ease of operation in accordance with the following priority list:

a. Reliability. Reliability is of prime importance and can be achieved by careful and thorough analysis, design, development, fabrication, and testing.

b. Flexibility. The work necessary to modify or change configurations, within the limitations of the system design, should be minimal in labor and time.

c. Maintainability. The system shall be reasonably simple to maintain and and shall be designed from a maintenance viewpoint. All components of the system should be modular, wherever possible, to facilitate maintenance and expansion.

d. Compatibility. The system should be capable of establishing the interconnections with the commercial telephone facilities specified herein and should be further capable of being equipped to establish any other type of interface, with other voice systems, which is not required at this time.

3.5 The SFOF Operational Voice Communications System (Figure 1) shall be composed of two four wire subsystems which shall be referred to as the Conference Subsystem and

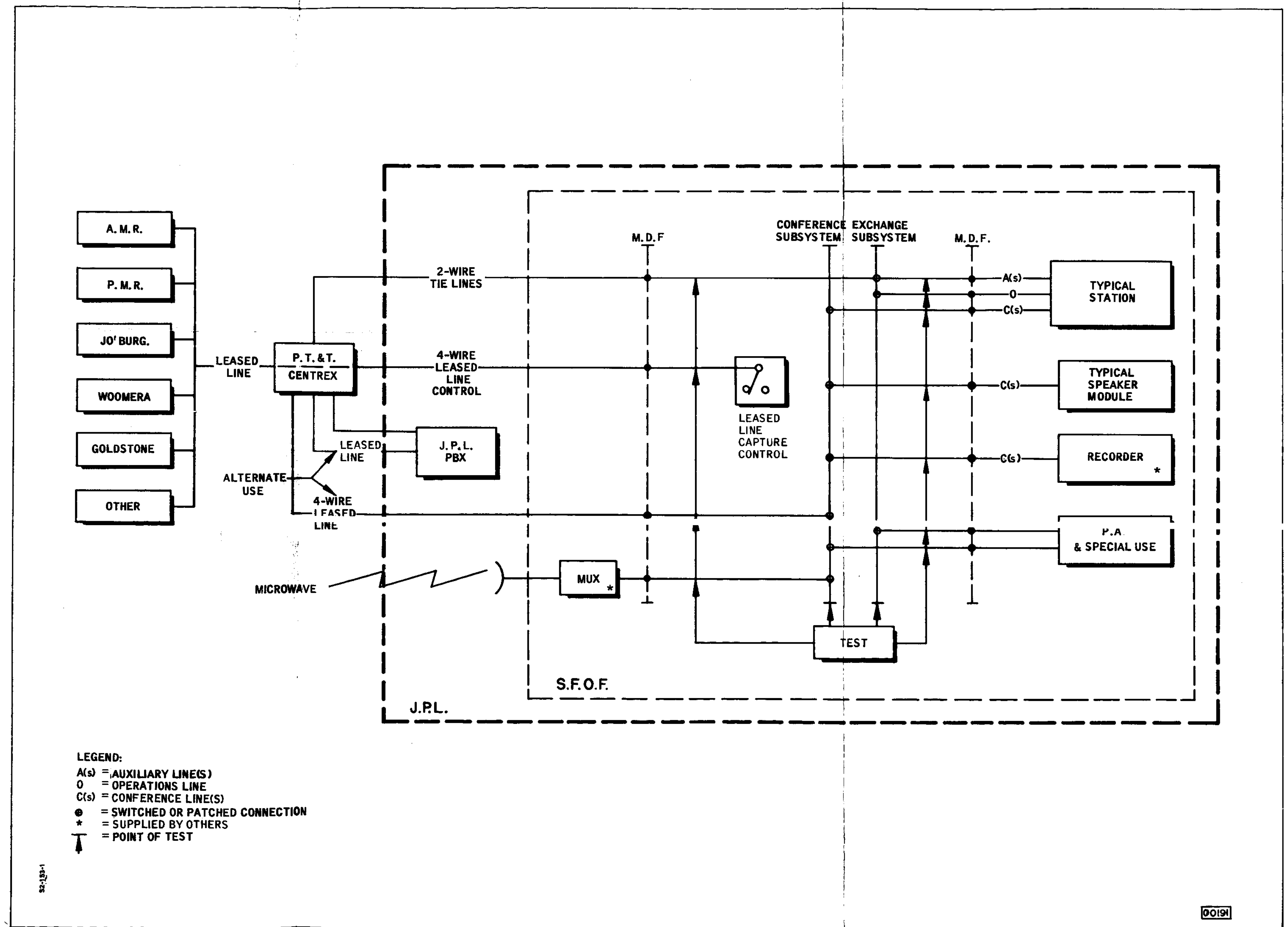

Figure E-1 SFOF Operational Voice Communication System and the Exchange Subsystem. These two subsystems may be integrated and operate as a single system, and may share common equipment.

3.5.1 Conference Subsystem. The Conference Subsystem (Figure 2) shall be capable of nineteen simulataneous conferences. Each conference shall be associated with an external four-wire voice line that will be leased from a local common carrier or will be a four-wire voice channel from the multiplexing equipment. The conferences will be entered by the users via their Headset Conference Selector Module or their Speaker Conference Selector Module

3.5.1.1 Connected serially with each pair of an external four-wire voice line and its associated conference shall be:

3.5.1.1.1 Half of a four winding repeat coil with the center terminals of the line side extended to a terminal block on the IDF for strapping or connection of signalling equipment.

3.5.1.1.2 A field of six bridged and normalled jacks.

3.5.1.1.3 A 15 db fixed attenuator and a 30 db line amplifier.

3.5.1.1.4 An enter control with an indicator light which will cause the external four-wire voice line to be removed from its associated conference.

3.5.1.2 Associated with each conference shall also be:

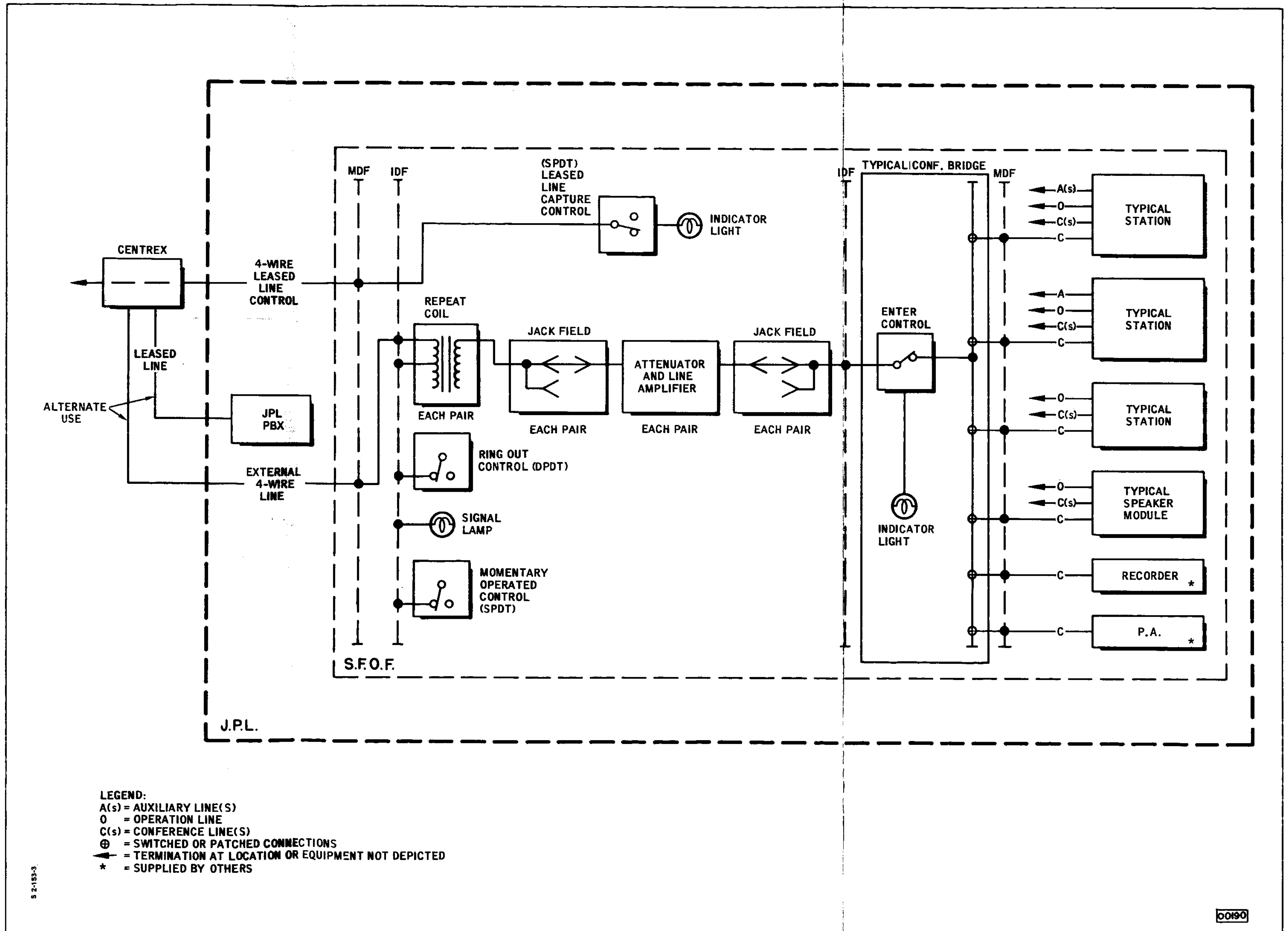

Figure E-2 Typical Conference in Conference Subsystem

3.5.1.2.1 A means of introducing an additional external four-wire voice line so that any one conference may have two external four-wire voice lines associated with it simultaneously.

3.5.1.2.2 A capture control switch with an indicator light which will provide single pole double throw contacts wired to the MDF. These contacts shall be used by others to control circuits that sieze external four-wire voice lines that are used for more than one purpose.

3.5.2.3 A ring out control providing double pole double throw contacts wired to the terminal block of 3.5.1.1.1 for incorporation of future signalling.

3.5.1.2.4 A signal lamp wired to the terminal block of 3.5.1.1.1.

3.5.1.2.5 A momentary operated control with single pole double throw contacts wired to the terminal block of 3.5.1.1.1.

3.5.1.2.6 Two independent, composite outputs for public address and recording purposes. Each output shall be capable of delivering 0 dbm to a 600 ohm load.

3.5.1.3 The conferences will each be able to conference the number of stations as shall be tabulated with its external line or lines.

3.5.1.3.1 An alternative which would be acceptable would be to have a limited access to the conferences whereby ten (10) stations could be given a priority such that they would have free and individual access to the conferences. Of the remaining stations able to participate, only twenty (20) of these could gain access. These twenty (20) stations would be determined on a first come first serve basis. This switched situation would not apply to the Speaker Conference Selector Modules.

3.5.1.4 Configurations of conferences shall be variable so that any one button on a Headset Conference Selector Module or on a Speaker Conference Selector Module can be equipped with accessibility to any conference.

3.5.1.4.1 Configurations shall be varied by means of a slip-in-preprogrammed patchboard, simplified strapping or some other unencumbered means. The receive and transmit sides will be connected such that a Headset Conference Selector Module can be equipped with a listen only capability.

3.5.1.4.2 If the option of 3.5.1.3.1 is exercised, the priority feature shall be an additional variable to care for in establishing configurations.

3.5.1.5 To care for unforeseen circumstances there shall be additional hardware as follows:

3.5.1.5.1 Six two-wire to four-wire hybrid circuits.

3.5.1.5.1.1 These hybrids shall be coil type with compromise networks and provision for installation of precision nets. The four-wire transmitting and the four-wire receiving paths shall each include a continuously variable 0 to 20 db attenuator. All line terminals are to be 600 ohms balanced and wired for jack panel access.

3.5.1.5.2 Twenty four-wire 30 db line amplifier - 15 db attenuator combinations of the same type as are associated with the Conference Subsystem. Half of these combinations will be equipped for jack panel access and half for wired circuit use with access to either side of the attenuator in both cases.

3.5.1.5.2.1 The line amplifiers shall have the following characteristics:

<u>Output Power</u> - Not less than 6 dbm continuous.

<u>Distortion</u> - Not more than 2% total at rated continuous output power levels.

<u>Gain</u> - Continuously variable from 0 to 30 db.

<u>Frequency Response</u> - +1 db from 300 to 3400 cps.

<u>Hum</u> - At least 60 db below specified output power level.

<u>Impedances</u> - Input and output impedances = 600 ohms balanced.

3.5.1.5.3 A field of 48 jacks of the same type as are associated with the Conference Subsystem. These shall be standard tip, ring and sleeve jacks with normally made tip and ring contacts. These jacks shall be wired to terminal blocks on the IDF for future applications. The sleeve connections of the jacks wired to the conferences shall also be suitably wired to terminal blocks.

3.5.2 <u>Exchange Subsystem.</u> The Exchange Subsystem (Figure 3) shall be a four-wire, telephone switching system with some special requirements.

3.5.2.1 When a busy terminal is called, the call shall camp on the busy line to establish a connection as soon as the line is idle.

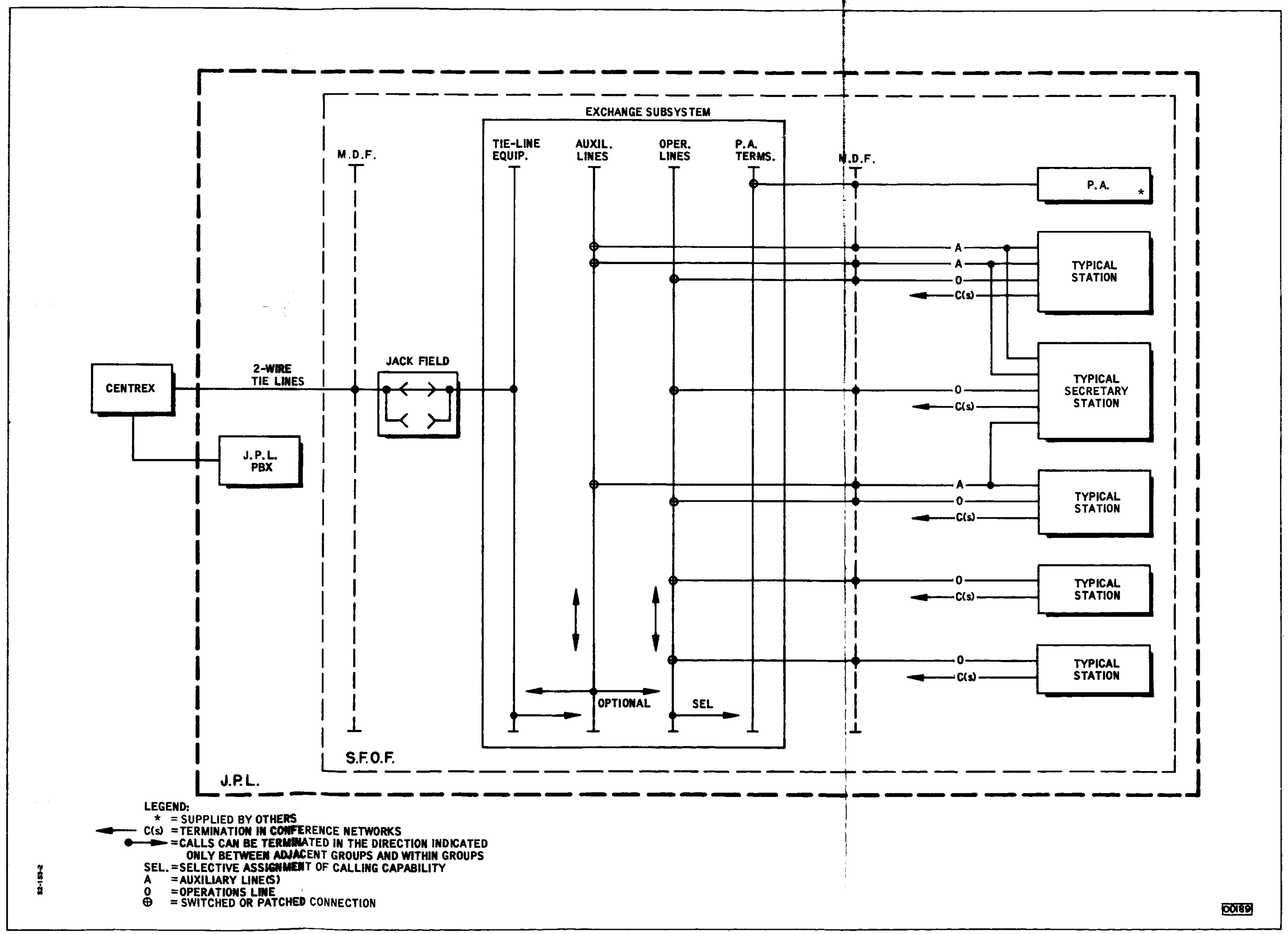

Figure E-3 Exchange Subsystem

3.5.2.1.1 The calling station shall be able to signal the called station that there is a call camped on the line.

3.5.2.1.2 Certain stations shall have a priority such that they will also be able to be connected to an existing call when they so desire. The calling and the called end shall both receive a signal indicating this connection has been established.

3.5.2.2 The system shall have twelve 5-party conference groups.

3.5.2.2.1 A conference shall be established by any station's successively digit keying the numbers of the desired stations.

3.5.2.2.2 If a station is busy when called for a conference, there shall be a signal indicating that station is busy and the call shall camp on the line but the busy signal shall not continue and interfere with the progress of the conference and the busy condition shall not deter the originator from obtaining additional conferees.

3.5.2.3 There shall be two-wire dial repeating tie lines for interconnection with the JPL administrative telephone system. Connected serially with a two wire tie line between the MDF and the Exchange Subsystem shall be a field of four bridged and normalled jacks.

3.5.2.3.1 A station interconnected to a tie line shall be able to transfer the call to another station with the proper priority.

3.5.2.3.2 A station receiving a call from a tie line shall be able to establish a conference connection. One of the parties called may be another tie line.

3.5.2.3.3 Those lines with access to and from the tie lines shall be called Auxiliary Lines. The rest of the lines from the Exchange Subsystem shall be called Operations Lines.

3.5.3 User Modules. Control of the Conference Subsystem and the Exchange Subsystem shall be achieved through the use of their respective termination modules at the user stations. These modules shall all conform to the dimensions indicated on JPL drawings (to be released later). All buttons shall be illuminated using a steady light for busy conditions and a flashing light for signalling.

3.5.3.1 Conference Selector Modules. Each user shall enter or monitor a pre-assigned conference in the Conference Subsystem via a Headset Conference Selector Module and/or a Speaker Conference Selector Module by depressing the applicable button. These modules shall be used in configurations of 6, 12, or 18 buttons. Those modules equipped with 6 buttons will be basically a 12 button configuration with a cover plate over the unused 6 button area.

3.5.3.1.1 The Speaker Conference Selector Module shall be used in conjunction with a Speaker Module with the volume control on the Speaker Conference Selector Module. The volume control shall be capable of varying the input to the Speaker Module from 1 milliwatt to 1 watt.

3.5.3.1.1.1 The Speaker Module shall have reasonable efficiency and be capable of 1 watt maximum input.

3.5.3.2 Exchange Subsystem Termination Module. Each user shall control and terminate the Exchange Subsystem via an Exchange Subsystem Termination Module. The controls considered necessary to achieve the desired functions may exist to a greater or lesser degree depending upon the actual design furnished.

3.5.3.2.1 The Speaker-Microphone combination with volume control and push-to-talk switch shall be normally associated with the Operations Line.

3.5.3.2.1.1 The speaker and volume control shall have the same characteristics as the Speaker Module and the volume control on the Speaker Conference Selector Module.

3.5.3.2.1.2 The microphone shall have sensitivity such that a user's voice from two feet away shall be reproduced at the same electrical level as if he were speaking into his headset transmitter. The sensitivity pattern of the microphone should be such that a minimum of room noise shall be reproduced. The microphone does not have to be a separate item from the speaker.

3.5.3.2.1.3 When the Speaker-Microphone is associated with the Operations Line an incoming call shall be automatically connected to the Speaker-Microphone and shall allow complete hands-free operation on the part of the called party to answer and proceed with the call.

3.5.3.2.1.4 The connection shall be established immediately and shall not be contingent upon the delay normally associated with a ringing cycle.

3.5.3.2.1.5 The calling and the called party shall both receive a signal indicating this connection has been established.

3.5.3.2.1.6 The push-to-talk operation shall be performed by the calling party only.

3.5.3.2.1.7 At termination of a call, both ends will be disconnected when the calling party disconnects.

3.5.3.2.2 The handset with hook switch shall be associated with the auxiliary lines.

3.5.3.2.2.1 The handset shall provide a quality of operation with respect to naturalness, intelligibility, and performance equal to or bette r than the Western Electric 500-type telephone set.

3.5.3.2.2.2 The handset cord when installed in a console shall be drawn into the body of the console by some mechanical means so that when a handset is placed on the hook switch a minimum amount of cord will be visible. The cord at the desk top mountings shall be retractile. All handset cords shall have a usable length of up to 4 feet.

3.5.3.2.2.3 The hook switch shall only disconnect the transmitter of the handset. The design of the hook switch shall be such that any perceptible motion shall be at a minimum so that a user will not receive the impression of disconnecting a line connection when placing the handset on the hook switch.

3.5.3.2.3 Each station shall be equipped with two sets of bridged headset jacks which shall not be normally associated with any type of line but will be under the control of the Headset Selector Buttons.

3.5.3.2.3.1 The headset shall be equipped with a cord mounted push-to-talk switch with a spring-restored and a locked-in position.

3.5.3.2.4 The Headset Selector Buttons shall be used for the option of connecting the headset to the Headset Conference Selector Module (C), the Operations Line (O), or the Auxiliary lines (A).

3.5.3.2.4.1 When the headset is associated with the Operations Line, the speaker-microphone shall be disconnected. When a station is in this mode, an incoming call will cause a normal audible and visible signal of the call and a manual operation will be required to answer the call.

3.5.3.2.5 The Headset Volume Control will be used to vary the receiver volume of the headset. The headset circuit shall be designed for use with headsets having the electrical and transmission properties of the Western Electric 52AW-type headset. The receiver circuit shall have enough output to compensate for a 12 db loss which is an inherent factor of certain headsets that will be used with the system.

3.5.3.2.6 To effect control of the Exchange Subsystem rather than a conventional rotary dial, the users shall be equipped with a ten digit key board.

3.5.3.2.7 The Dial Selector Buttons shall be used to associate the Digit Key Board with the Operations Line or the Auxiliary Line.

3.5.3.2.8 The Operations Line Button shall be used to alert the Exchange Subsystem (signal for dial tone) that a call is about to be made with the use of the Digit Key Board and shall also be used to answer an incoming call when the Operations Line is in the headset mode.

3.5.3.2.9 The Preset Calling Buttons shall be used to establish calls that are made frequently. Depressing one of these buttons shall be the equivalent of depressing the Operations Line Button and keying the three digits of another station in the SFOF. It shall be possible to depress these buttons consecutively for use when establishing a conference in the Exchange Subsystem. These buttons shall be used in configurations of 6 or 12 buttons.

3.5.3.2.10 The Operations Line Release Button shall be used for terminating a call on the Operations line in any mode except an incoming call in the Speaker-Microphone mode.

3.5.3.2.11 The Hot Call Button shall be used to signal a busy station that there is a call camped on the line.

3.5.3.2.12 The Break-in Button shall be used to break in on a busy connection. This capability shall be assigned selectively.

3.5.3.2.13 The Auxiliary Line Selection Buttons shall be used in the same manner as the Operations Line Button.

3.5.3.2.13.1 These lines shall be equipped with an automatic holding feature. The buttons shall be interlocked to the degree that when a second button is depressed the first line shall be disconnected from the handset (and headset if so switched) but the interconnection through the Exchange Subsystem shall be held intact.

3.5.3.2.14 The Auxiliary Line Release Button shall be used to terminate a call on the last Auxiliary Line Selection Button depressed.

3.5.3.2.15 The Audible Signal Volume Control shall be used to vary the volume of the incoming call alerting signal of the auxiliary lines only.

3.5.3.3. The various modules shall either be mounted in the face of a console or in a unit that will be free standing on a desk.

3.5.3.3.1 There will be four types of desk units incorporating different combinations of modules as follows;

A. Speaker Module and Speaker Conference Selector Module

B. Exchange Subsystem Termination Module

C. Exchange Subsystem Termination Module and Headset Conference Selector Module

D. Type A and Type C combined

3.5.3.3.1.1 Those Desk Units equipped with an auxiliary line shall have a handset jack and a hook switch which can be readily added to or removed from the left hand side of the Desk Unit.

3.5.3.3.2 The headset jacks shall be installed under the writing shelf of a console or in the base of the Desk Units.

3.5.3.4 All installation procedures shall conform to JPL specifications.

3.5.3.4.1 All station cables shall be run in a concealed manner from the Communications Terminal Room to the station with no intermediate terminations or splices.

3.5.3.4.2 The station cables shall be at least 24 gauge cable of good commercial quality.

3.5.3.4.3 Each station will be fed by only one multi-conductor cable with 50% spare pairs for maintenance and expansion.

3.5.3.4.4 The station cables shall terminate at the stations in multiprong female jacks. All pairs shall be soldered or mechanically wrapped on both ends.

3.6 Transmission Characteristics

3.6.1 The following requirements shall be required for any cross office connection of stations.

3.6.1.1 Amplitude versus frequency loss between 300 - 3400 cps $= \pm 1$ db.

3.6.1.2 Insertion loss at 1000 cps $= 0 \pm 1$ db

3.6.1.3 Intelligible crosstalk coupling shall not exceed -55db between equal level points.

3.6.1.4 The envelope delay distortion shall not exceed 20 microseconds for any two frequencies between 1000 and 2500 cps.

3.6.1.5 In a circuit, noise pulses of greater than 1 microsecond duration due to switching in another circuit, shall not have a peak voltage greater than 1% of the equivalent peak voltage of 1 mw in the circuit considered.

3.6.1.6 In a circuit, noise pulses of greater than 1 microsecond duration due to switching in that circuit, shall not have a peak voltage greater than 10% of the equivalent peak voltage of 1 mw in the circuit considered.

3.6.2 Sidetone at a station shall be 20db below the receive level.

3.6.3 At points of interconnection with external lines the level shall be either as follows or as required by the common carrier.

Level

Transmitting = -16dbm

Receiving = +7dbm

Impedance

600 ohms balanced

Return loss vs. 600 ohms = 26db min.

3.6.3.1 There shall be a minimum of 50db isolation between the transmit and receive portions of any external four-wire line.

3.7 <u>Testing and maintenance</u>. The system shall have materials and equipment necessary to test and maintain the system and its interfaces except for common hand tools.

3.7.1 It shall be possible to test, isolate and repair difficulties such as transmission, signalling, power supplies and switching with maximum efficiency and speed to minimize the down time of the system and any of its components and interfaces.

3.7.2 Complete documentation of all equipment in the form of all types of drawings, circuit descriptions, test procedures, maintenance procedures, and operating instructions, shall be supplied by the contractor.

3.7.3 The contractor shall recommend methods of making traffic studies to increase the efficiency of application of the system.

3.8 Reliability requirements of the system are of prime importance. These requirements shall be met or exceeded. If these requirements introduce excessive implementation of redundancy in the designs, the bidder shall give specific details in his proposal.

3.8.1 User Modules.

A failure of a User Module shall be defined as a failure of any element exclusive of the handset and headset cords, that will consequently degrade the performance of the module.

The user modules shall have a Mean Down Time in place (MDT) of 7 minutes with a probability (P) of 0.99 that the Down Time in place (DT) shall not exceed 10 minutes.

The user modules shall have a Mean Time Between Failures (MTBF) of 24,000 hours.

3.8.2 Exchange Subsystem.

A major failure of the Exchange Subsystem shall be defined as a failure that affects the system in such a manner that the degradation of performance is experienced by any user.

A minor failure shall be defined as a failure that affects the system in such a manner that the degradation of performance is experienced by users in a statistical manner, such as a failure of a link.

A line failure shall be defined as a failure that degrades the performance of an individual line exclusively or a group of lines.

Type of Failure	MTBF, hrs.	MDT, min.	P= 0.99:DT min.
Major	5,000	3	5
Minor	240	10	15
Line	240	7	10

3.8.3 Conference Subsystem.

A failure shall be defined in the same manner as for the Exchange Subsystem.

Type of Failure	MTBF, hrs.	MDT, min.	P= 0.99:DT min.
Major	10,000	3	4
Minor	1,000	7	10
Line	500	7	10

3.9 Packaging. A minimum number of different components and values of components should be used.

3.9.1 All panel layouts and user station equipment shall conform to accepted human engineering, industrial, design practices. Reasonable use of color as an operating and identifying aid is encouraged.

3.9.2 Painting, engraving and enclosures.

3.9.2.1 All exposed panel faces of all user modules and cabinets shall be custom painted in accordance with JPL specifications, and all permanent panel markings shall be engraved per JPL specifications.

3.9.2.2 All switching, conferencing, control and other terminal room equipment shall be enclosed in standard 19 inch racks approximately 7 feet high to be furnished by JPL.

3.9.2.3 The permanent markings on all, switching, conferencing, control, and other terminal equipment shall be engraved and shall conform to JPL specifications.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General Quality Assurance Provisions

4.1.1 Contractor Inspection. The contractor is responsible for the performance of all component, module, and/or subassembly testing to assure the product conforms to all the requirements specified.

The manufacturer may utilize his own or any other inspection facilities and services acceptable to JPL. Inspection records of examinations and tests shall be kept complete and available to JPL. JPL reserves the right to perform any of the inspections and tests where such inspections or tests are deemed necessary to assure supplies and services conform to prescribed requirements. The overall system test and evaluation shall be the joint responsibility of the supplier and the JPL cognizant engineer. The JPL inspection team will make periodic inspection of material, workmanship, and assembly techniques of the system.

4.1.1.1 In-process controls. The manufacturer shall establish and maintain a system in-process inspection and controls of production quality, with particular regard for control of characteristics that are not readily detectable or measurable in the finished product. The characteristics to be measured and the methods of inspection and control shall be determined by the manufacturer, subject to the approval of JPL. Contractor quality control shall meet the requirements of JPL Specification 20025.

4.2 Inspection provisions.

4.2.1 Lot size. For the purpose of sampling, a lot schall consist of all items of the same type, manufactured in one production run, and offered for delivery at the same time.

4.2.2 Test program

4.2.2.1 Visual examination. Visual examination of the units shall be conducted for the purpose of determining compliance with the requirements specified.

4.2.2.2 Testing. The system shall be tested by the vendor to determine full compliance with this specification. The system shall be capable of meeting all performance requirements specified herein.

4.3 Rejection and resubmittal. Individual units or lots, as applicable, which do not meet all requirements of this specification shall be rejected and returned to the contractor. Before resubmittal, full particulars concerning the previous rejection and the action taken to correct the defects shall be furnished JPL.

5.0 PREPARATION FOR DELIVERY. Preservation, packaging, and packing for delivery should be in accordance with the contract or procurement document.

DESIGN SPECIFICATION EXTRACT

APPENDIX F

TELETYPE SWITCHING SYSTEM FOR THE JPL-SFOF

The items discussed here have been abstracted from the specification and are organized in the following manner:

Distribution Method
Teletype End Instruments
Control Devices and Methods
Equipment Location
Switching Facilities
Displays and Indications

DISTRIBUTION METHOD

The basic distribution method employed in the Teletype System has been predicated on the operational need for multiple numbers of receiving end instruments to be connected to and monitor any teletype circuit available to the SFOF. The actual distribution of the teletype circuits has been effected through the use of the direct connected end instruments in the case of the recording functions and through the use of switching facilities in the case of all the other end instruments. To accomplish the multiple connection feature, the following special converters are employed:

a. Series/Parallel Bidirectional Circuit Converter

b. Parallel/Series Bidirectional Circuit Converter

All 36 incoming and 36 outgoing teletype circuits are identifiable by the switching facilities, and thus the control devices, according to the geographical locations of the circuits. Identifications are by abbreviated word form descriptions of the individual circuits.

All internal teletype circuits will be wired as four wire systems although system utilization will require only two of the four wires. All end instruments will utilize receptacles as required by the design. Wiring cables for the interfaces to the other SFOF subsystems will be connected to pins.

Series/Parallel Bidirectional Circuit Converter. The Series/Parallel Circuit Converter is used at each incoming teletype circuit at the line side of the Main Switching Unit and at each outgoing teletype circuit at the loop side of the Main Switching Unit. This Converter re-configures the electrical characteristics of the line or loop circuits such that they may be distributed, through the Main Switching Unit, to multiple receiving end instruments or circuits. Conventional series distribution methods are avoided because of inherent limitations in switching and loading associated with these methods. The end instrument capacity of the Series/Parallel Converters is sufficient to allow for the 100% utilization case in which all end instruments may be connected to the same circuit. Thus, the converters permit operation of multiple numbers of end instruments from one single teletype circuit.

Parallel/Series Bidirectional Circuit Converter. The Parallel/Series Circuit Converter is used at each receiving end instrument on the loop side of the Main Switching Unit and at each outgoing teletype circuit on the line side of the Main Switching Unit. This Converter re-configures the electrical characteristics of the previously series-to-parallel converted circuits such that they appear as standard teletype circuits at individual end instruments or circuits. Conventional series distribution methods are avoided because of inherent limitations in switching and loading associated with these methods. Thus, although the circuit distributions are effected in a parallel manner, individual end instruments and circuits function as standard teletype end instruments and circuits.

TELETYPE END INSTRUMENTS

The SFOF Teletype System requires the use of certain standard and special purpose teletype equipment as end instruments capable of operation at 60 words per minute. Certain of the end instruments will be furnished by Jet Propulsion Laboratory and are denoted as JPLFE in the following compilation of the basic types of teletype end instruments required:

1. Receive-Only Page Printer (JPLFE)
2. Send-Receive Page Printer (JPLFE)
3. Tape Punch Typing Perforator (JPLFE)
4. Tape Punch Typing Reperforator (JPLFE)
5. Tape Reader Transmitter (JPLFE)
6. Teletype/Computer Keyer (CFE)
7. Computer/Teletype Keyer (CFE)

CONTROL DEVICES AND METHODS

Four basic types of control devices are used to effect the control of receiving and transmitting teletype messages. These four are the Communications Technical Coordinator's Panel, the Communications Data Distributor's Panel, the Selector Boxes, and the Channel Selectors.

The two panels consist of the basic means for orienting circuits, controlling the distribution of incoming teletype messages, and controlling the distribution of outgoing teletype messages and establishing connections to allow SFOF areas and rooms to be capable of transmitting outgoing messages. The Selector Boxes facilitate the selection of incoming circuits by users for monitoring purposes. The Channel Selectors facilitate the selection of incoming and outgoing teletype circuits and the Area Surveillance Telecasts which users may desire to monitor on the Closed Circuit Television System.

The Communications Technical Coordinator's Panel is used for effecting technical control and orientation of all incoming and outgoing teletype circuits. The panel will consist of two similar sections associated with incoming and outgoing circuits respectively (viz., the Incoming Section and the Outgoing Section). Figure F-1 illustrates the Communications Technical Coordinators Panel layout.

The incoming section is used as the means for controlling the orientation of external incoming teletype circuits with the pre-designated internal incoming teletype circuits and will facilitate the entry of technical status information into the teletype display portions of the entire SFOF Communications System. This section is configured as 4 groups of control button modules and 2 indicator light modules as follows (from top to bottom):

1. Traffic Indicator Module

2. Distortion Indicator Module

3. Line Status Module

4. Line Assignment Module

5. Teletype Monitor Module Number 1

6. Teletype Monitor Module Number 2

The outgoing section is used for controlling the orientation of external outgoing teletype circuits with the pre-designated internal outgoing teletype circuits and will facilitate the entry of technical status information into the teletype display portions of the entire SFOF Communications System. This section is configured as 4 control button modules and 2 indicator light modules as follows:

1. Traffic Indicator Module

2. Distortion Indicator Module

3. Line Status Module

4. Line Assignment Module

5. Distant Lines to Distant Lines Module

The Communications Data Distributor Panel is used for controlling the distribution of teletype circuits for certain incoming and all outgoing teletype circuits. The panel consists of two somewhat similar sections associated with incoming and outgoing circuits respectively (viz., the Incoming Section and the Outgoing Section). Figure F-2 illustrates the Communications Data Distributor Panel layout.

The incoming section is used for controlling the distribution of incoming teletype circuits to certain users relying on the Communications Data Distributor Panel for switching of these circuits. It facilitates the entry of

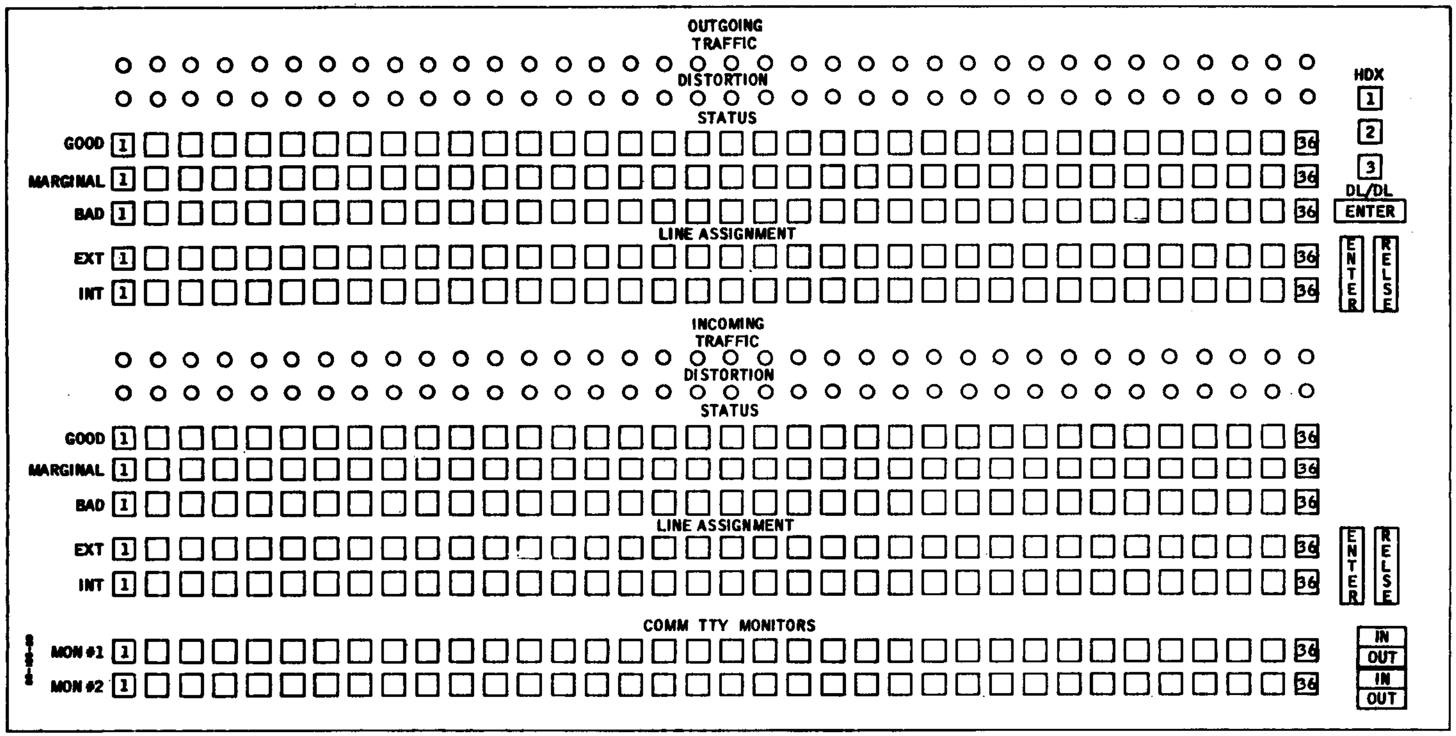

Figure F-1 Communications Technical Coordinators Panel Layout

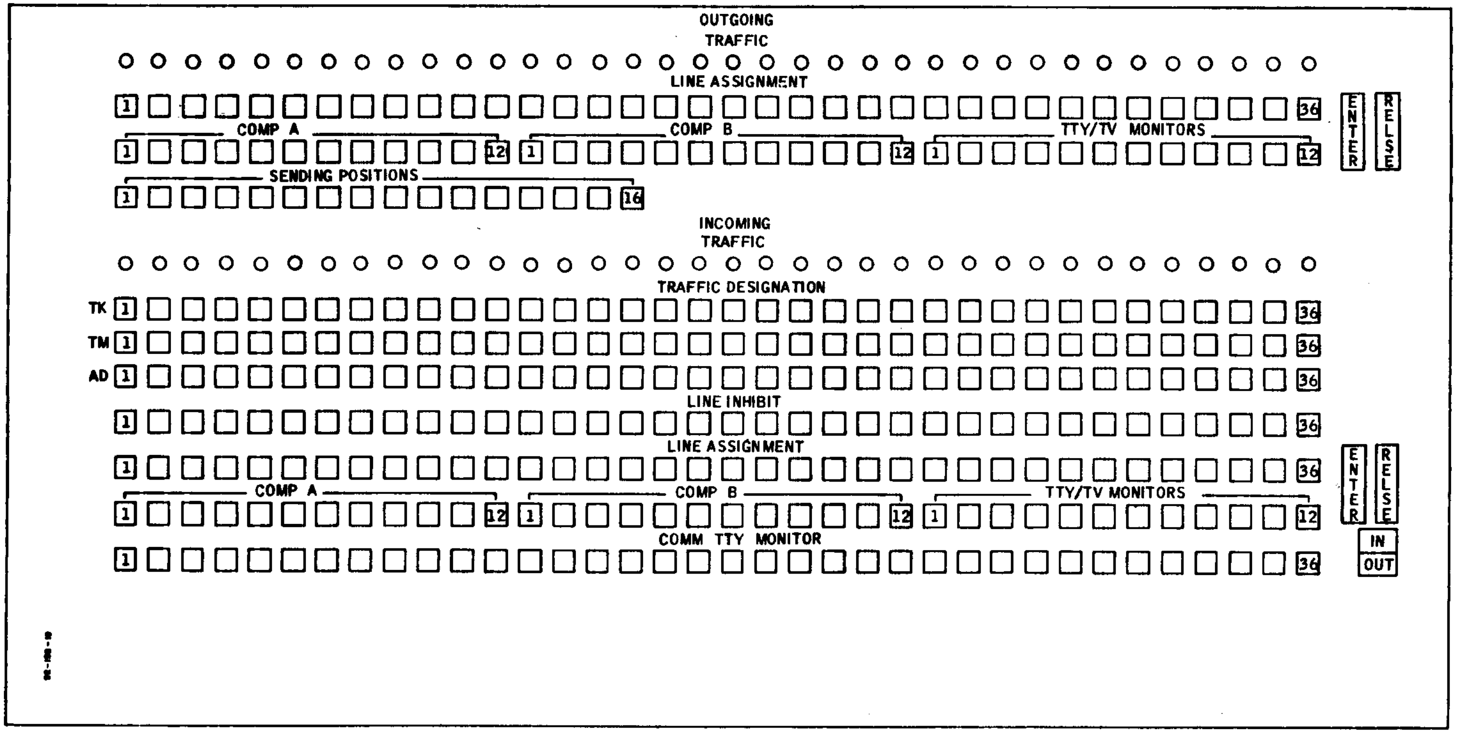

Figure F-2 Communications Data Distributor Panel Layout traffic identification into the teletype display portions of the SFOF Communications System and enables the denial of all incoming teletype circuits to selected users. The section is configured as 4 control button modules and 1 indicator light module as follows (from top to bottom):

1. Traffic Indicator Module

2. Traffic Designation Module

3. Line Inhibit Module

4. Internal Line Assignment Module

5. Teletype Monitor Module Number 3

The outgoing section is used as the means for controlling the distribution of outgoing teletype circuits from certain users relying on the Communications Data Distributor Panel for switching of these circuits and facilitates the entry of traffic identification into the teletype display portions of the entire SFOF Communications System. The section is configured as 1 control button module and 1 indicator light module as follows (from top to bottom):

1. Traffic Indicator Module

2. Internal Line Assignment Module

<u>Selector Box.</u> The Selector Box is used at all user stations associated with oriented incoming teletype circuits and is used in conjunction with each end instrument (except the computer/teletype buffers and teletype/computer buffers and the end instruments in Printer/Camera combinations). The Selector Box consists of 36 indicator-pushbuttons, each one individually and uniquely associated with each one of the 36 incoming teletype circuits. (See Figure F-3.) Each indicator-pushbutton of the Selector Box is permanently marked with the circuit identification for the particular circuit which that indicator-pushbutton controls.

<u>Channel Selector.</u> The Channel Selector is used at all user Television Monitors, and consists of 3 groups of indicator-pushbuttons. The first group contains 36 indicator-pushbuttons, each one of which is designated and uniquely and permanently associated respectively with the 36 oriented incoming teletype circuits capable of being monitored by the 12 Incoming Circuit Printer/Camera combinations. The second group contains 8 indicator-pushbuttons, 6 of which are commonly associated with the 36 oriented outgoing teletype circuits capable of being monitored by the 6 Outgoing circuit Printer/Camera combinations, and 2 of which are spares. The third group contains 16 indicator-pushbuttons which are associated with the various Television Cameras used for area surveillance, the pushbuttons being so indicated. (See Figure F-4.)

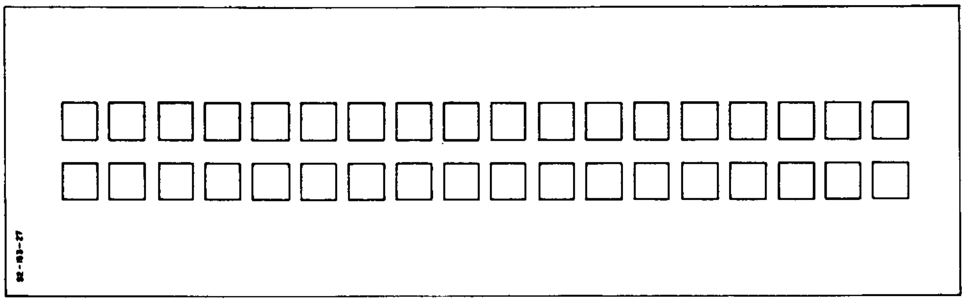

Figure F-3 Selector Box Panel Layout

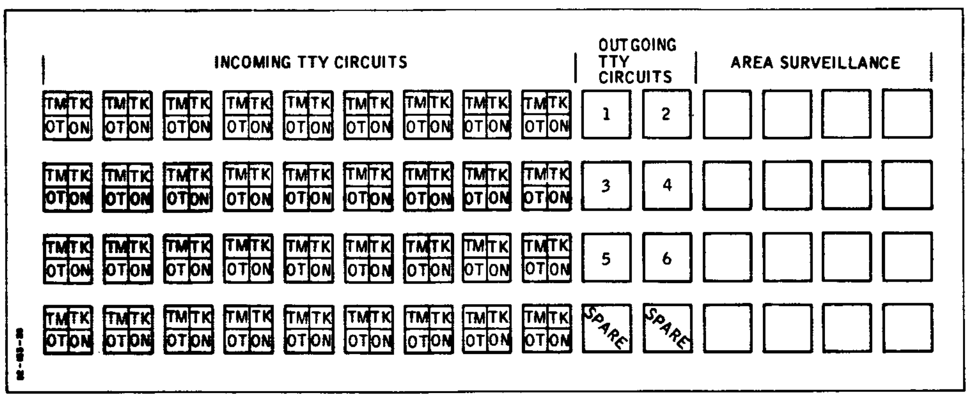

Figure F-4 Channel Selector Panel Layout

EQUIPMENT LOCATION

The Teletype Subsystem end instrument and control equipment is configured and located in accordance with the details in this paragraph. Illustrations of the end instrument arrangements are shown in portions of Figures 7 through 14 and 16 through 22. The Areas and Rooms for this equipment are listed in the next paragraph.

SWITCHING FACILITIES

The Teletype System contains switching facilities sufficient and adequate to provide the switching operations required for efficient and effective usage of the SFOF Teletype System. The switching facility requirements divide functionally into seven switching units for purposes of definition and description. The seven switching units are shown in Figure F-5 and are named as follows:

a. Incoming Circuit Orient Switching Unit

b. Outgoing Circuit Orient Switching Unit

c. Main Switching Unit

d. Incoming Circuit Non-Oriented Switching Unit

e. Outgoing Circuit Non-Oriented Switching Unit

f. Distant Lines to Distant Lines Switching Unit

g. Half-Duplex Conference Switching Unit

The Main Switching Unit has interfaces with the Incoming Circuit Orient Switching Unit and the Outgoing Circuit Orient Switching Unit. The output of the Incoming Circuit Orient Switching Unit is the input to the Main Switching Unit, and the output of the Main Switching Unit is the input to the Outgoing Circuit Orient Switching Unit. The Half-Duplex Conference Switching Unit has an interface with the Distant Lines to Distant Lines Switching Unit. All other switching units interface directly with the non-oriented incoming circuits or non-oriented outgoing circuits.

Portions of Figure F-5 have been expanded to include the switching functions for the related end instruments and are presented in Figures F-6 through F-21 which are organized by rooms and areas as follows:

Incoming Circuit Orient Switching Unit. This switching unit consists of a 36 by 36 switching matrix, one side of which is representative of and connected to the 36 non-oriented incoming teletype circuits, and the other side of which is representative of and connected to the 36 oriented (or permanently designated) internal teletype circuits which serve as inputs to the Main Switching Unit. The Incoming Circuit Orient Switching Unit serves to orient the incoming teletype circuits such that they will always appear according to their geographical designations. Control of this switching unit

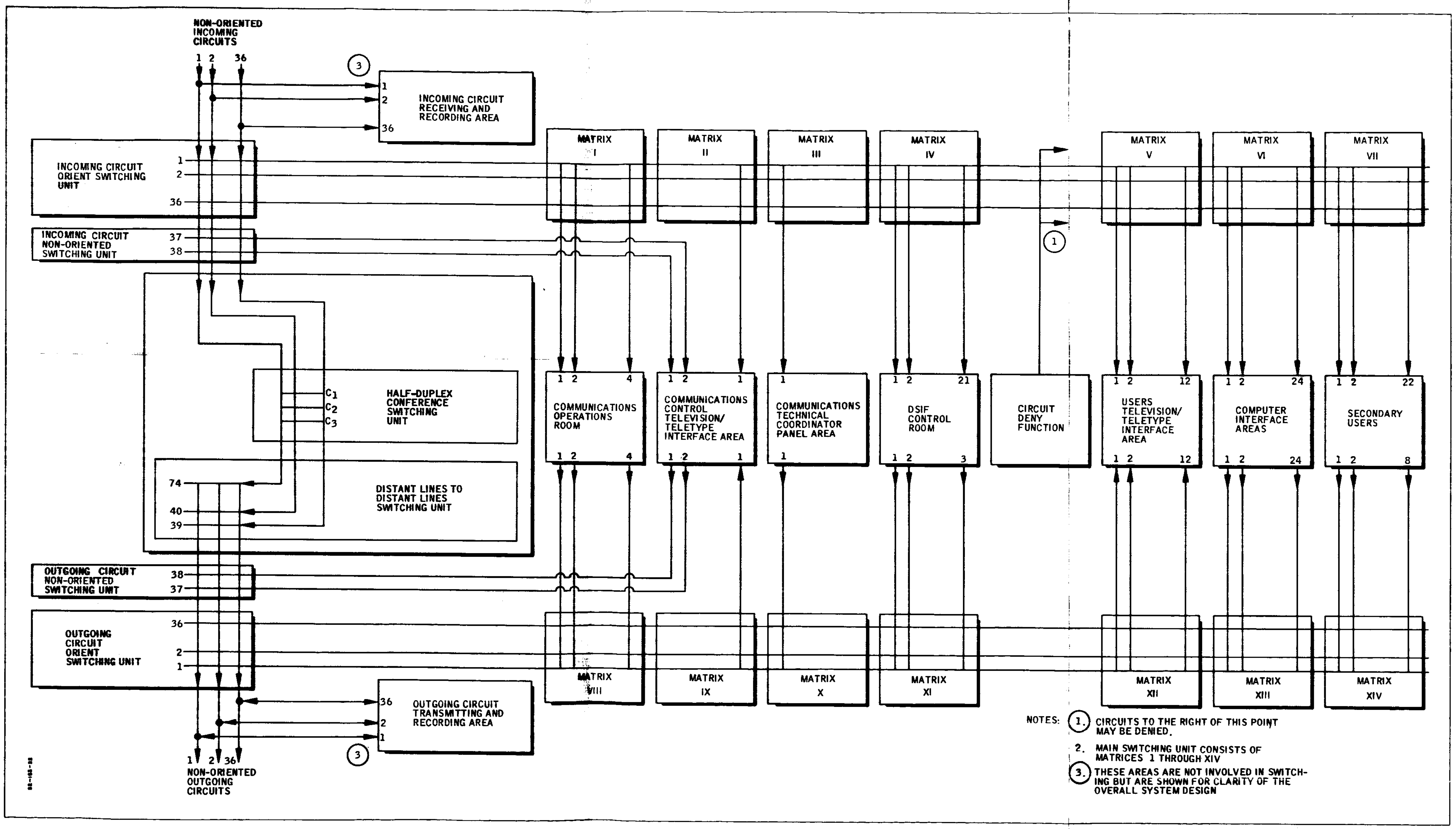

Figure F-5 Teletype Subsystem Switching Functions

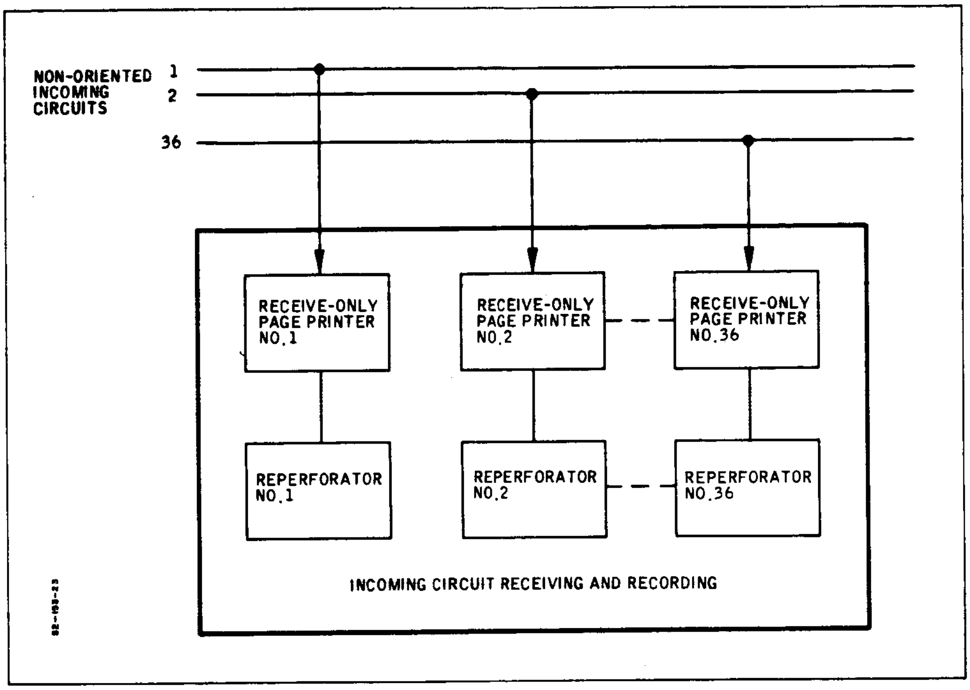

Figure F-6 Incoming Circuit Receiving and Recording Area Switching Functions

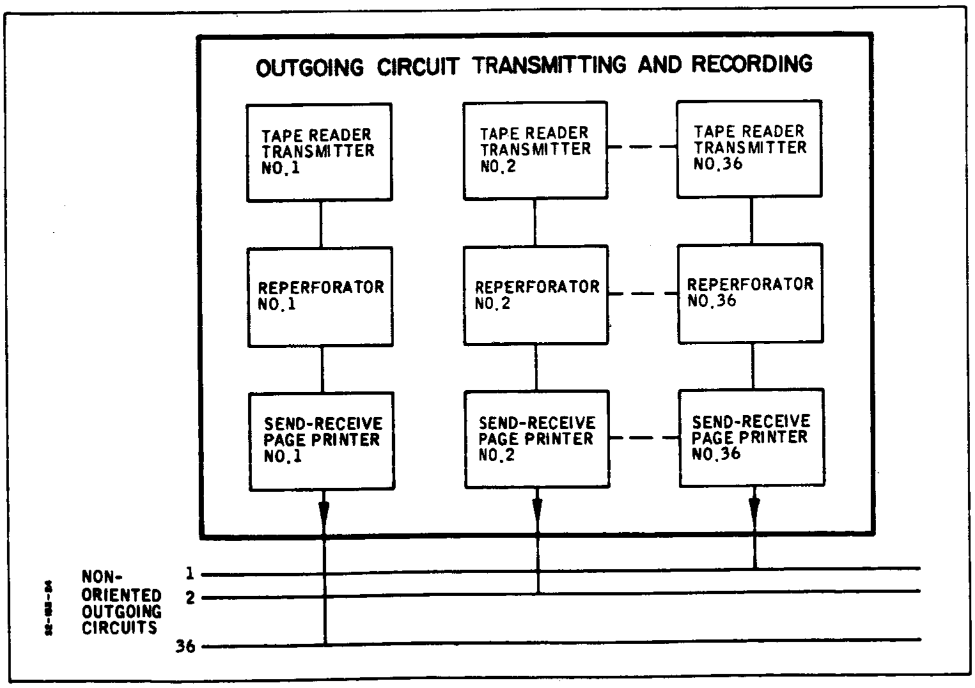

Figure F-7 Outgoing Circuit Trans. and Recording Area Switching Functions

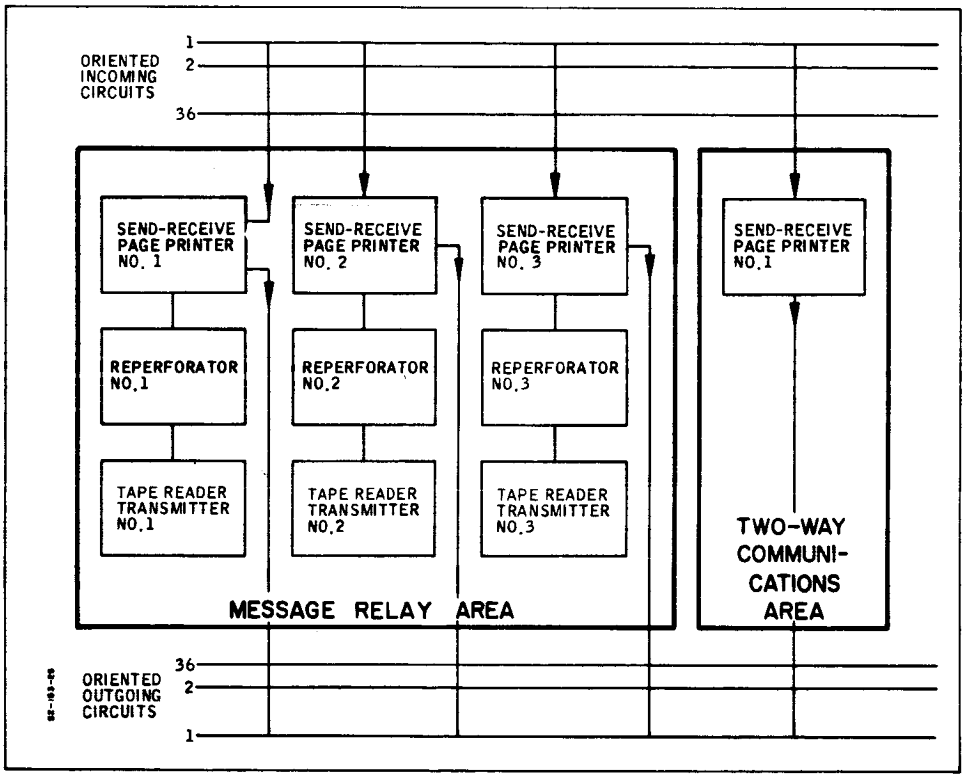

Figure F-8 Communications Operations Room Switching Functions

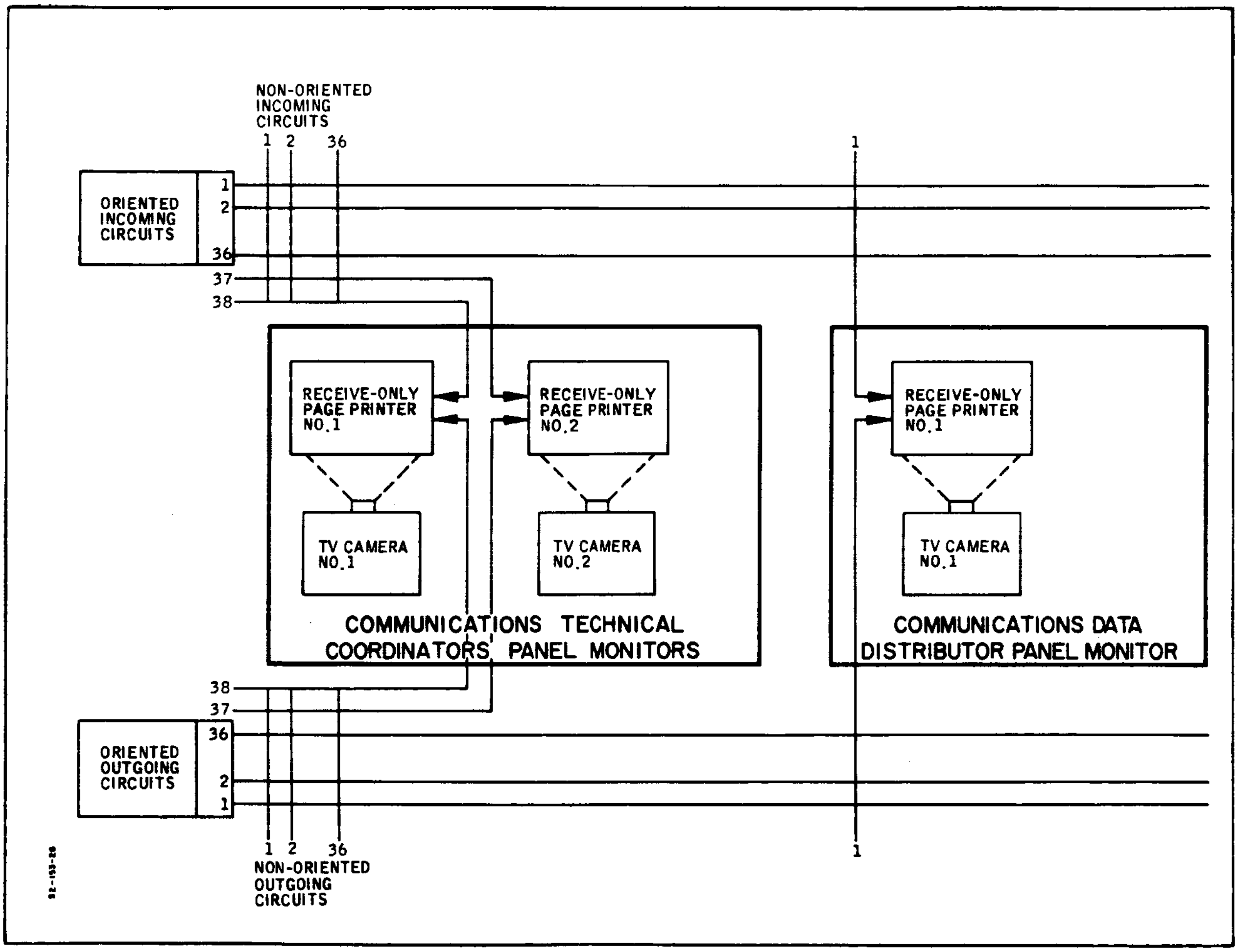

Figure F-9 Communications Control Television/Teletype Interface Area Switching Functions

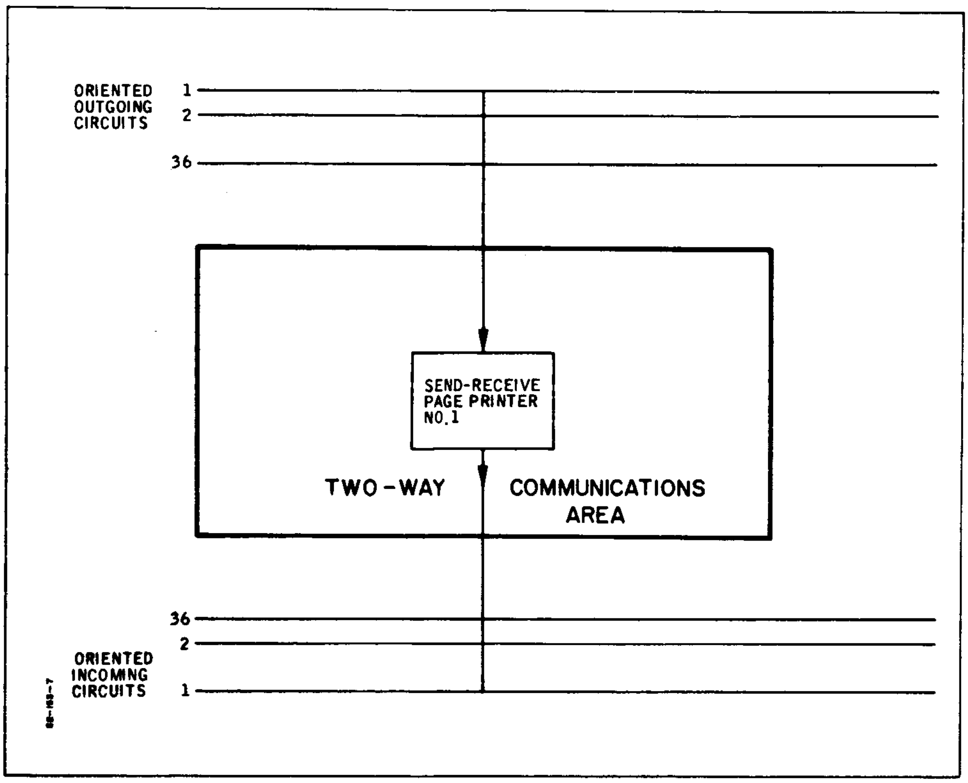

Figure 10 Communications Technical Coordinator Panel Area Switching Functions

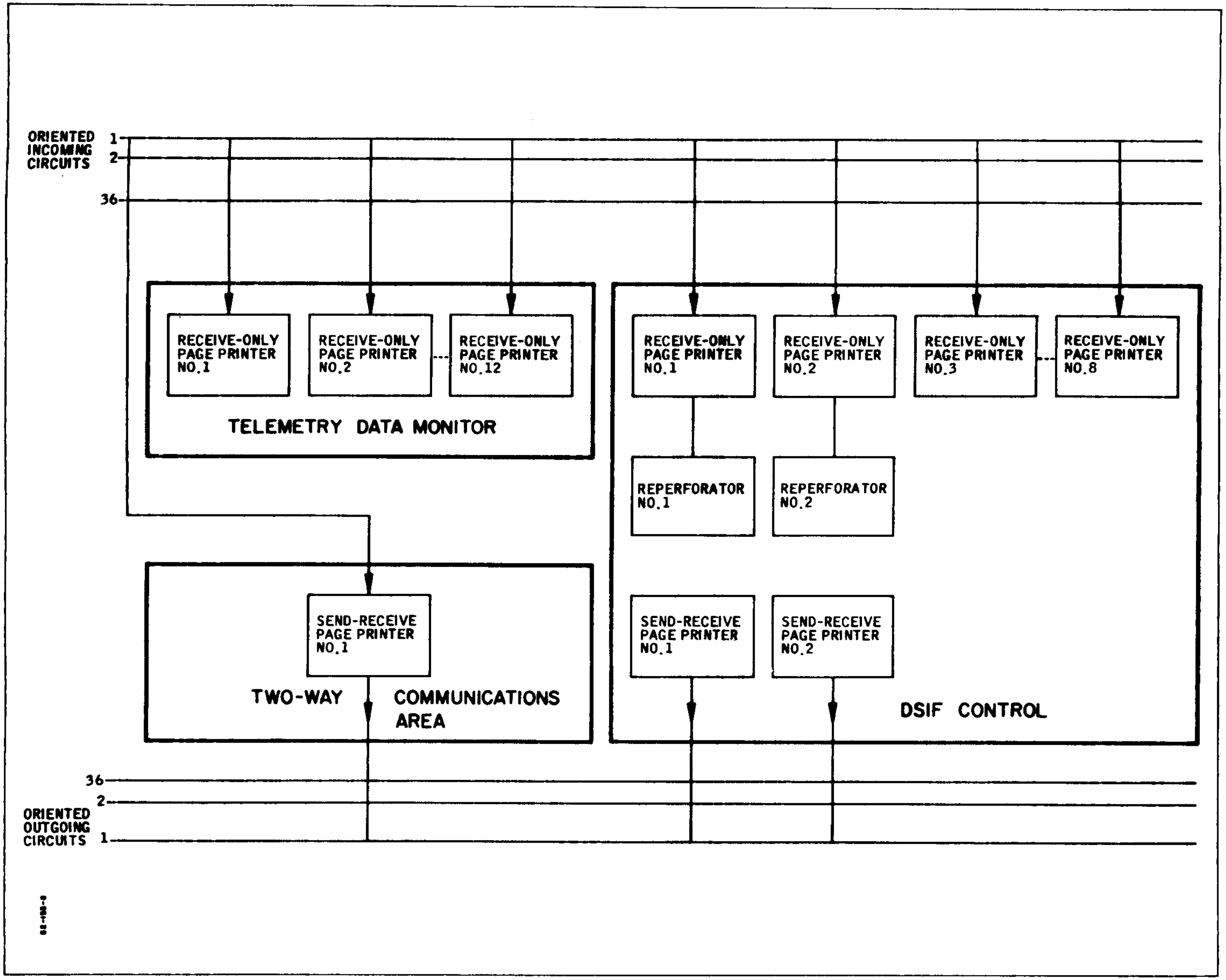

Figure F-11 DSIF Control Room Switching Functions

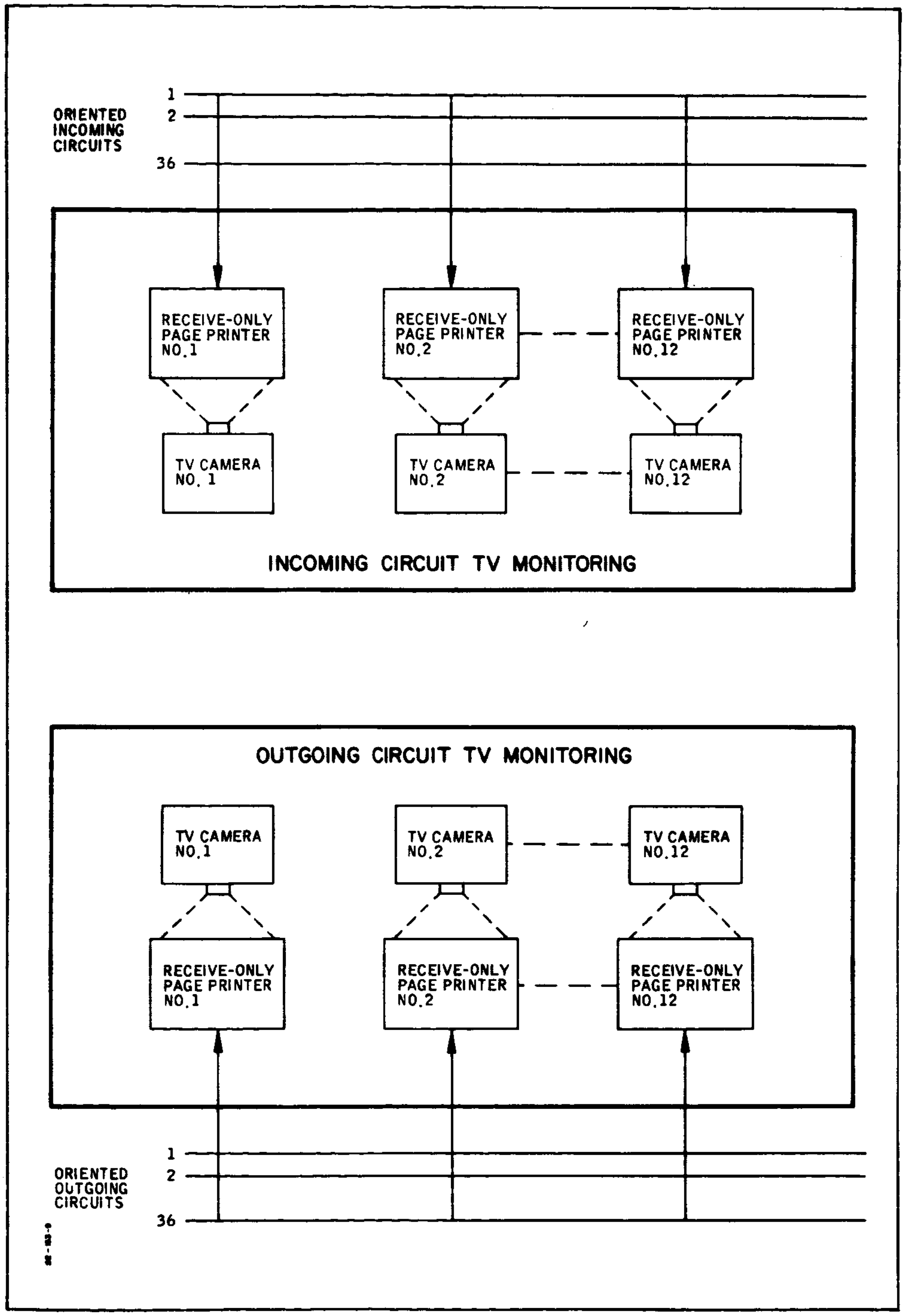

Figure F-12 Users Television/Teletype Interface Area Switching Functions

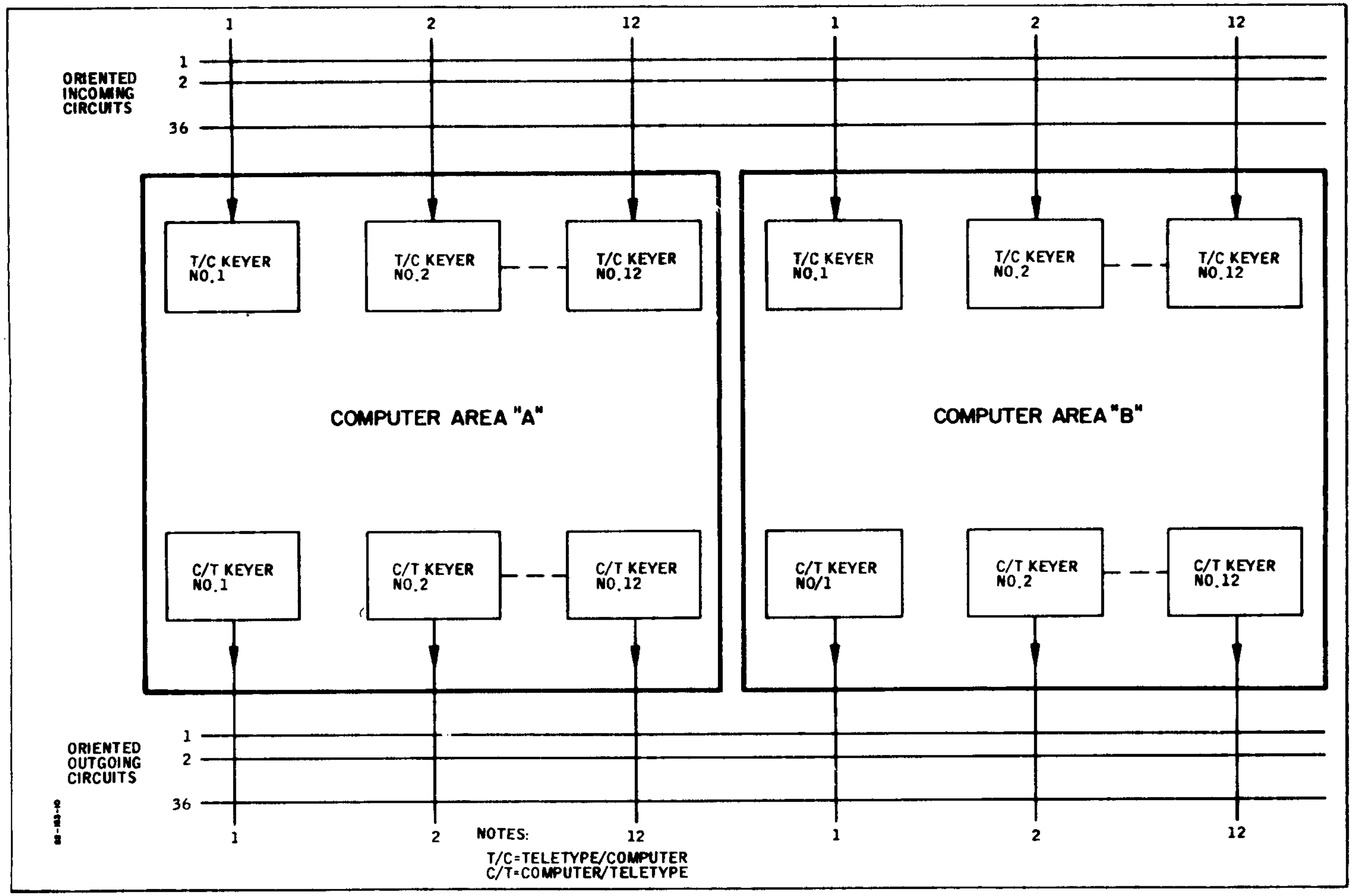

Figure F-13 Computer Interface Areas Switching Functions

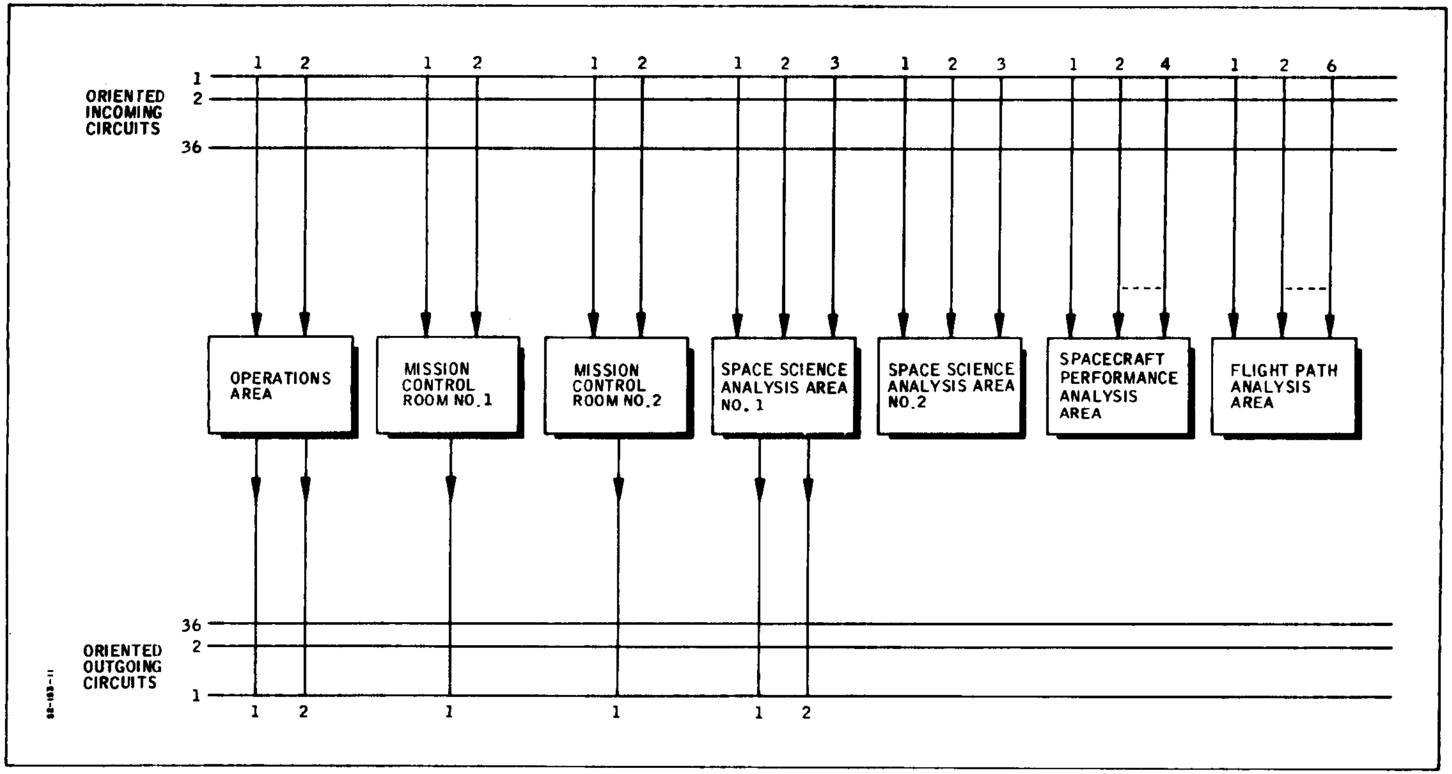

Figure F-14 Secondary Users Switching Functions

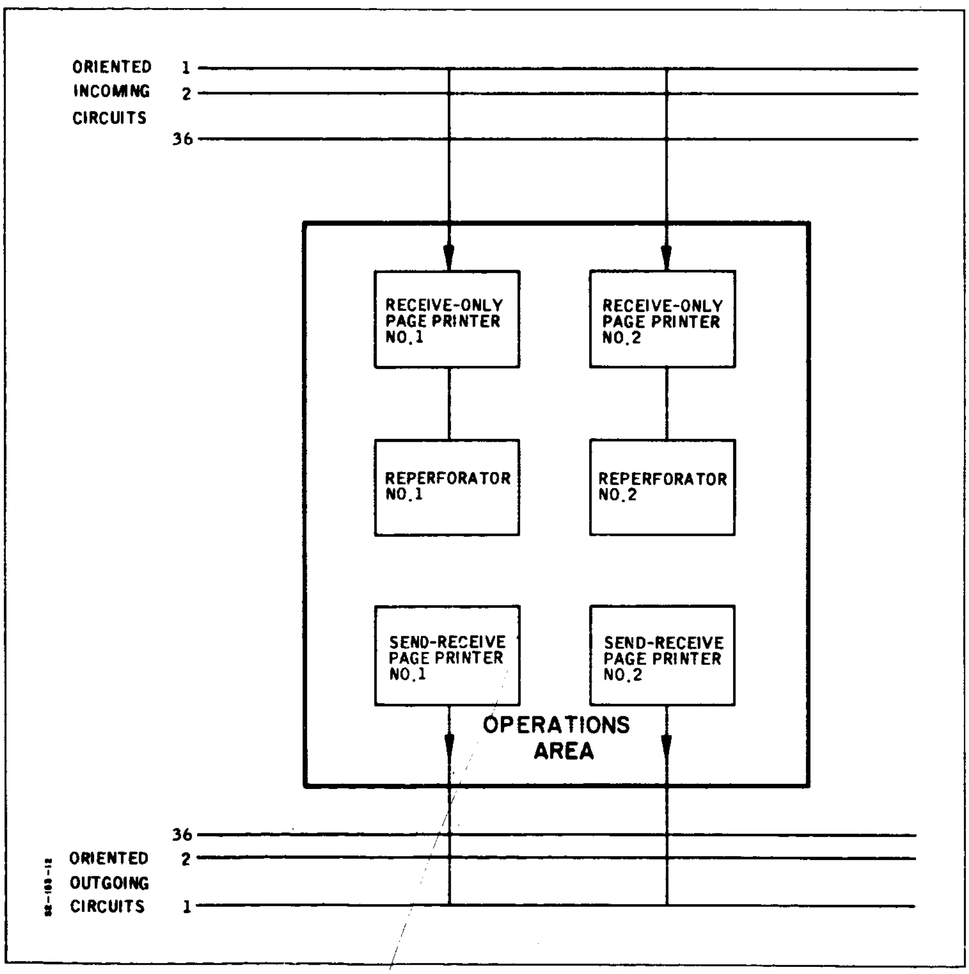

Figure F-15 Operations Area Switching Functions

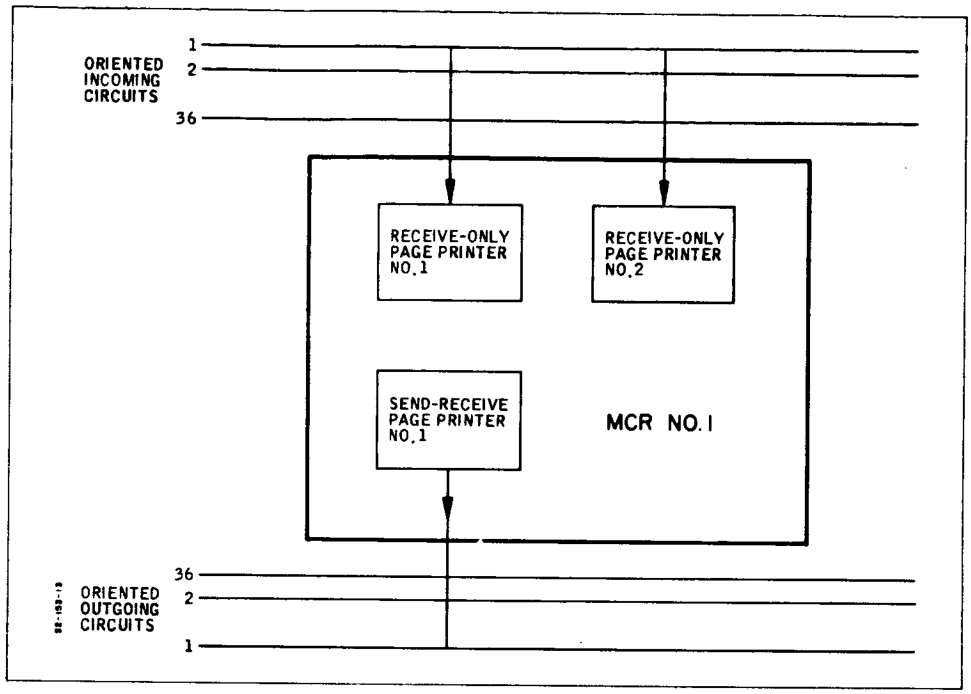

Figure F-16 Mission Control Room Number 1 Switching Functions

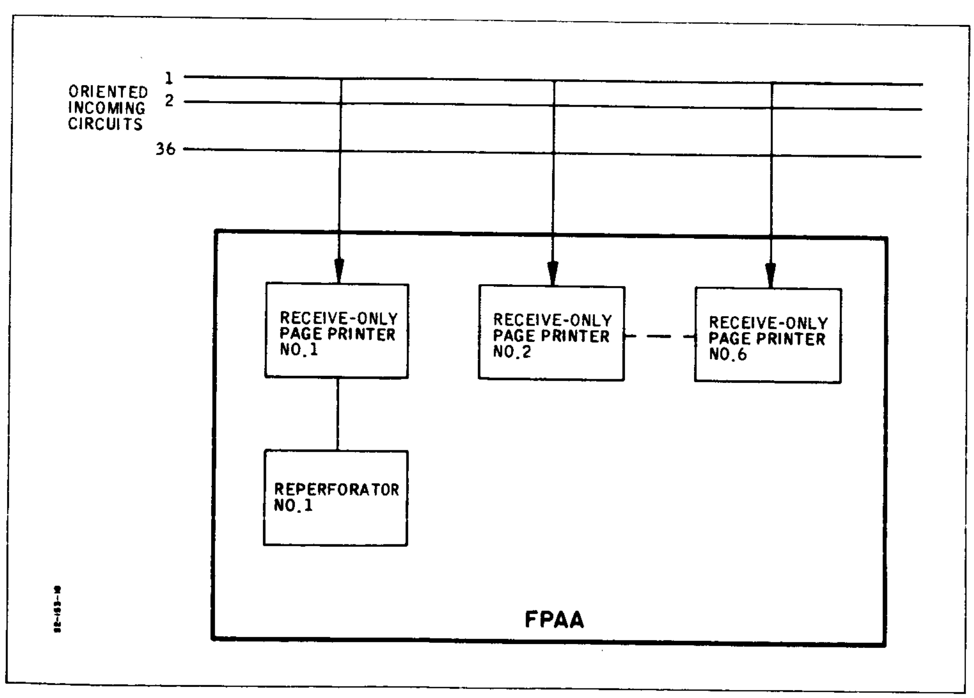

Figure F-17 Mission Control Room Number 2 Switching Functions

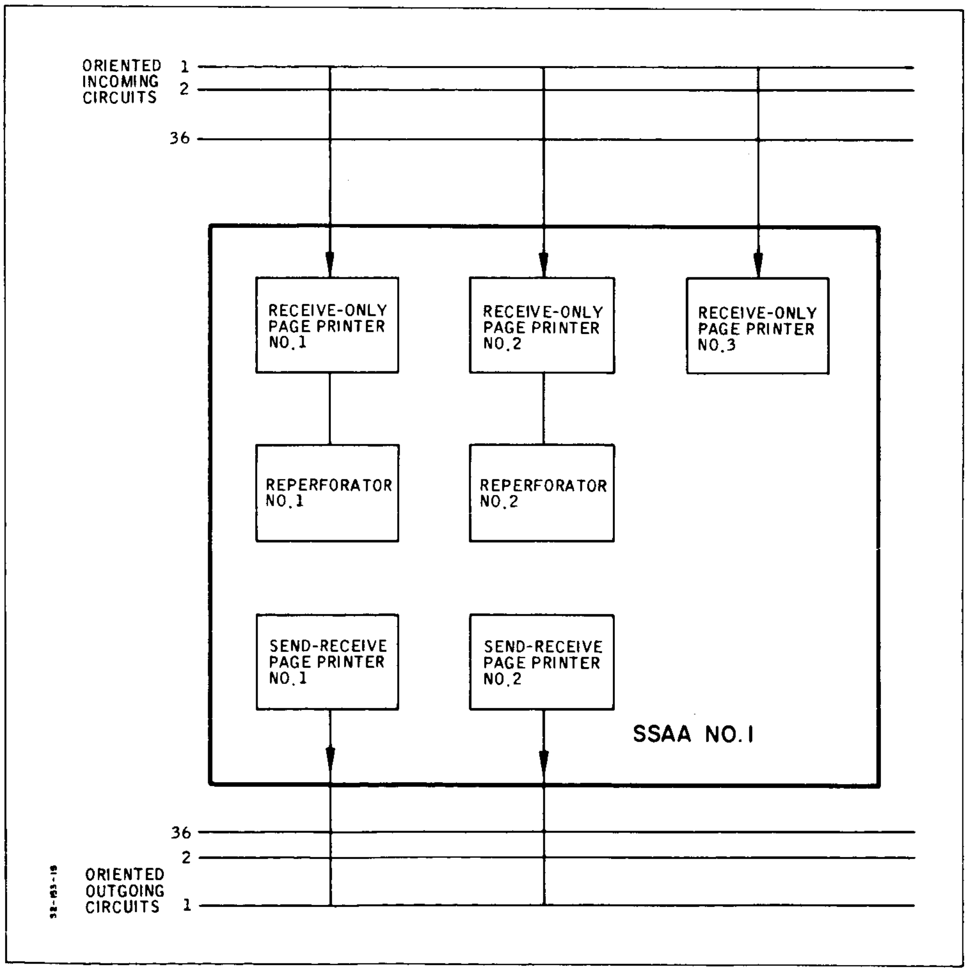

Figure F-18 Space Science Analysis Area Number 1 Switching Functions

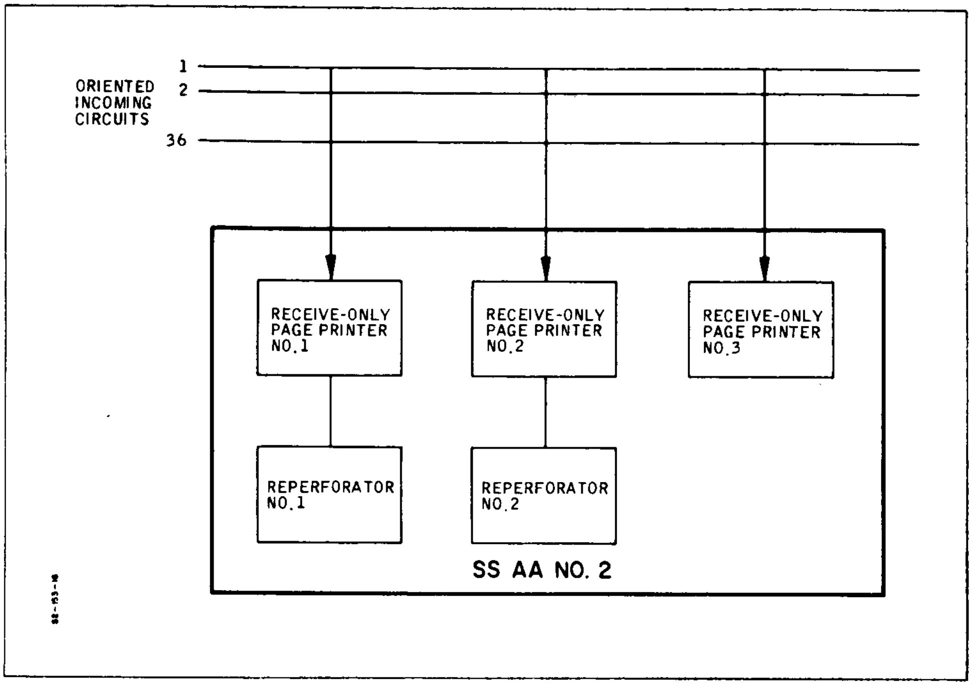

Figure F-19 Space Science Analysis Area Number 2 Switching Functions

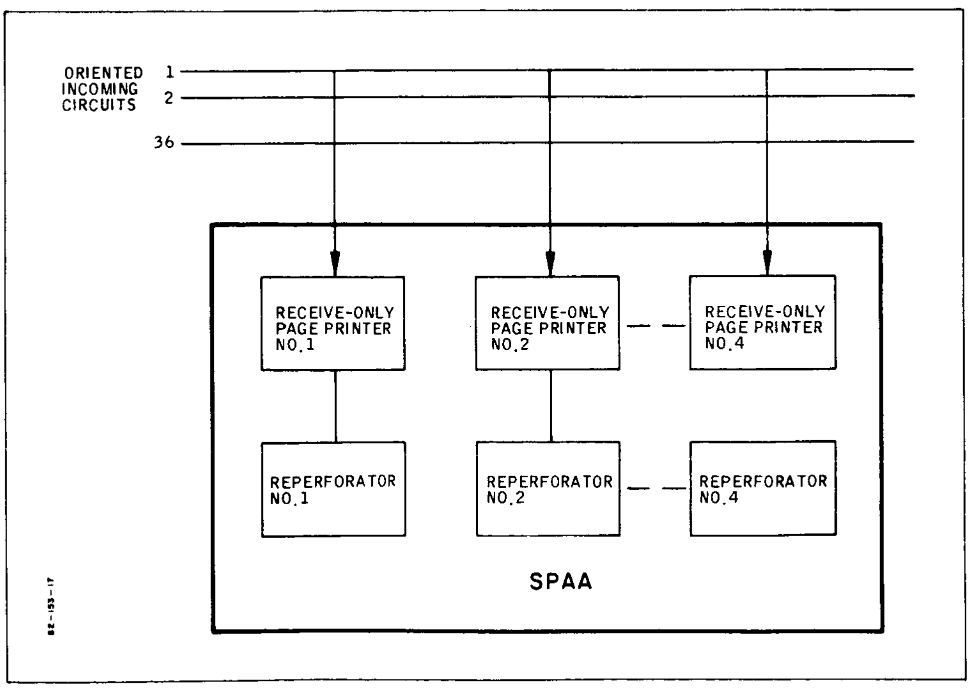

Figure F-20 Spacecraft Performance Analysis Area Switching Functions

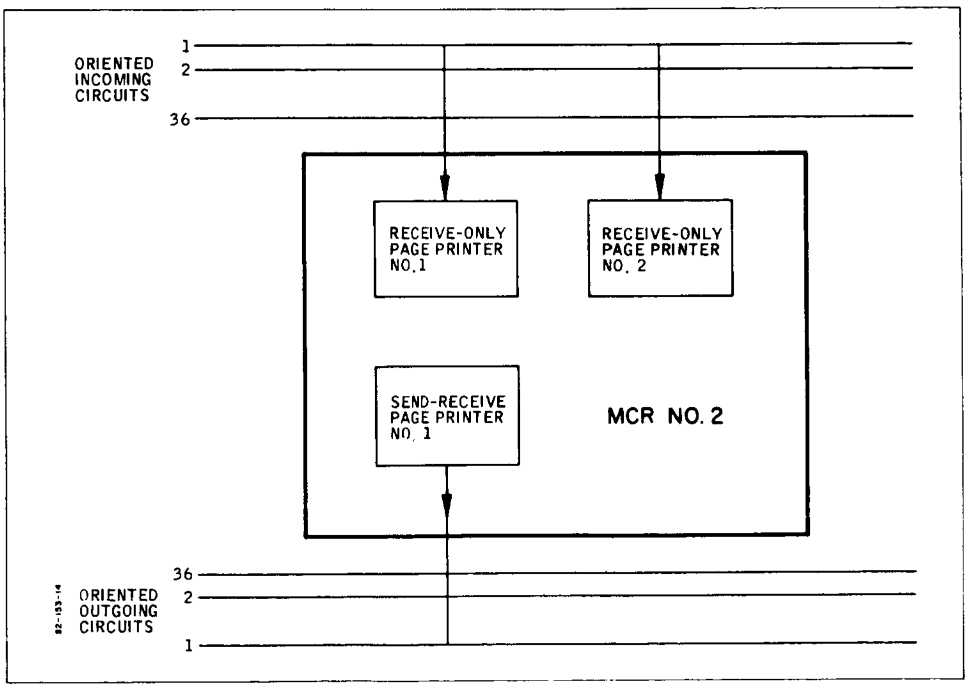

Figure F-21 Flight Path Analysis Area Switching Functions emanates from the Communications Technical Coordinator Panel, Incoming Section. A secondary function of the Incoming Circuit Orient Switching Unit is to effect the distribution of various control signals which activate certain displays.

Outgoing Circuit Orient Switching Unit. This switching unit consists of a 36 by 36 switching matrix, one side of which is representative of and connected to the 36 non-oriented outgoing teletype circuits, and the other side of which is representative of and connected to the 36 oriented (or permanently designated) internal teletype circuits which serve as outputs from the Main Switching Unit. The Outgoing Circuit Orient Switching Unit serves to orient the outgoing teletype circuits such that they always appear according to their geographical designations. Control of this switching unit emanates from the Communications Technical Coordinator Panel, Outgoing Section. A secondary function of the Outgoing Circuit Orient Switching Unit is to effect the distribution of various control signals which activate certain displays.

Main Switching Unit. This switching unit consists of 14 switching matrices, 7 of which are associated with the 36 oriented teletype circuits at the Incoming Circuit Orient Switching Unit, and 7 of which are associated with the 36 oriented teletype circuits at the Outgoing Circuit Orient Switching Unit. The 14 matrices of the Main Switching Unit serve as the means for connecting the SFOF teletype users to the oriented incoming and outgoing teletype circuits (through the respective orient switching units). Matrices numbered I through VII are permanently connected to and organized with the oriented incoming circuits and matrices numbered VIII through XIV are permanently connected to and organized with the oriented outgoing circuits. Matrices V, VI, and VII are subject to inhibition or denial. Table F-1 summarizes the 14 matrices and the users of the Main Switching Unit.

Incoming Circuit Non-Oriented Switching Unit. This switching unit consists of a 2 by 36 switching matrix, one side of which is representative of and connected to the 36 non-oriented incoming teletype circuits, and the other side of which is representative of and connected to the 2 internal teletype circuits to the end instruments for receiving non-oriented incoming circuits in the Communications Control Television/Teletype Interface Area. The Incoming Circuit Non-Oriented Switching Unit serves as the means for connecting the end instruments to any one of the non-oriented incoming circuits. Control of this switching unit emanates from the Communications Technical Coordinator Panel. Teletype Monitor Module Number 1 controls one of the internal teletype circuits; Teletype Monitor Module Number 2 controls the other internal teletype circuit. A secondary function of the Incoming Circuit Non-Oriented Switching Unit is to effect the distribution of various control signals which activate certain displays.

Outgoing Circuit Non-Oriented Switching Unit. This switching unit consists of a 2 by 36 switching matrix, one side of which is representative of and connected to the 36 non-oriented outgoing teletype circuits, and the other side of which is representative of and connected to the 2 internal teletype circuits to the end instruments for monitoring the non-oriented outgoing circuits in the Communications Control Television/Teletype Interface Area. The Outgoing Circuit Non-Oriented Switching Unit serves as the

Table F-1 Main Switching Unit Users and Matrices

User	Oriented Circuit	Matrix Number
Communications Operations Room	Incoming	I
	Outgoing	VIII
Communications Control Television/ Teletype Interface Area	Incoming	II
	Outgoing	IX
Communications Technical Coordinator Panel Area	Incoming	III
	Outgoing	X
DSIF Control Room	Incoming	IV
	Outgoing	XI
Users' Television/ Teletype Interface Area	Incoming	V
	Outgoing	XII
Computer Interface Areas	Incoming	VI
	Outgoing	XIII
Secondary Users	Incoming	VII
	Outgoing	XIV

means for connecting the end instruments to any one of the non-oriented outgoing circuits. Control of this switching unit emanates from the Communications Technical Coordinator Panel: Teletype Monitor Module Number 1 controls one of the internal teletype circuits; Teletype Monitor Module Number 2 controls the other internal teletype circuit. A secondary function of the Outgoing Circuit Non-Oriented Switching Unit is to effect the distribution of various control signals which will activate certain displays.

Distant Lines to Distant Lines Switching Unit. This switching unit consists of a 36 by 36 switching matrix, one side of which is representative of and connected to the 36 non-oriented incoming teletype circuits (through the Half-Duplex Conference Switching Unit), and the other side of which is representative of and connected to the 36 non-oriented outgoing teletype circuits. The Distant Lines to Distant Lines Switching Unit serves as the means for connecting the non-oriented incoming circuits to any number (up to all) of the non-oriented outgoing circuits (but no more than one non-oriented incoming circuit may be connected to a group of non-oriented outgoing circuits at a time, although several such connections may be made simultaneously). Thus, world wide switching is effected wherein any number of geographical locations may receive the message but only one location may transmit when the switching unit is in that particular configuration. Control of this switching unit emanates from the Distant Lines to Distant Lines Module on the Communications Technical Coordinator's Panel. A secondary function of the Distant Lines to Distant Lines Switching Unit is to effect the distribution of various control signals which activate certain displays.

Half-Duplex Conference Switching Unit. This switching unit consists of a 3 by 36 switching matrix in which the 3-element portion consists of 3 separate links, each one of which has access to all 36 links in the 36-element portion. Each one of the 36 links in the 36-element portion is connected respectively to one of the 36 non-oriented incoming circuits and to one of the 36 inputs to the Distant Lines to Distant Lines Switching Unit. The Half-Duplex Conference Switching Unit serves as the means for connecting any number (up to all) of the non-oriented incoming circuits together for the purpose of effecting a conference of several geographical locations in which any or all locations may transmit a message when the switching unit is in that particular configuration. Thus, the Half-Duplex Conference Switching Unit is used in conjunction with the Distant Lines to Distant Lines Switching Unit. When these units are so used, world wide conference switching is effected wherein any number of geographical locations may both transmit and receive messages. Up to 3 such conferences may be established at a given time. Control of this switching unit emanates from the Distant Lines to Distant Lines Module of the Communications Technical Coordinators Panel. A secondary function of the Half-Duplex Conference Switching Unit is to effect the distribution of various control signals which activate certain displays.

Switching Control Devices. The SFOF Teletype System requires the use of several special purpose control devices to actuate (enable or inhibit) the various teletype switching units and the Video Switching Unit (not a part of this system), to provide the operations desired. Table II lists all of the control functions performed within the Teletype System and indicates the control devices from which these control functions are effected.

TABLE F-2

CONTROL OF SWITCHING

SWITCHING FUNCTION	CONTROL DEVICE	CONTROL LOCATION	SWITCHING DEVICE
Orient Incoming Circuits	Line Assignment Module	Incoming Section of the Communications Technical Panel Coordinator	Incoming Circuit Orient Switching Unit
Orient Outgoing Circuits	Line Assignment Module	Outgoing Section of the Communications Technical Panel Coordinator	Outgoing Circuit Orient Switching Unit
Switch One Non-Oriented Incoming Circuit to One or More Non-Oriented Circuit	Distant Lines to Distant Lines Module	Outgoing Section of the Communications Technical Coordinators Panel	Distant Lines to Distant Lines Switching Unit
Switch One or More Non-Oriented Incoming Circuits to One or More Non-Oriented Outgoing Circuits	Distant Lines to Distant Lines Module	Outgoing Section of the Communications Technical Coordinators Panel	Half-Duplex Conference Switching Unit in Conjunction with Distant Lines to Distant Lines Switching Unit
Select Circuits for Communications Control Television/Teletype Interface (Teletype Television Monitors)			
Non-Oriented Incoming or Outgoing Circuits	Teletype Monitor Module Number 1	Incoming Section of the Communications Technical Coordinators Panel	Incoming Circuit Non-Oriented Switching Unit or Outgoing Circuit Non-Oriented Switching Unit
Non-Oriented Incoming or Outgoing Circuits	Teletype Monitor Module Number 2	Incoming Section of the Communications Technical Coordinators Panel	Incoming Circuit Non-Oriented Switching Unit or Outgoing Circuit Non-Oriented Switching Unit
Oriented Incoming or Outgoing Circuits	Teletype Monitor Module Number 3	Incoming Section of the Communications Data Distributor Panel	Matrix II or Matrix IX of Main Switching Unit
Deny Oriented Incoming Circuits			
By DSIF Control Room	DSIF Control Room Console (Not a Part of This Teletype Specification)	DSIF Control Room	Matrices V, VI, and VII of Main Switching Unit
By Communications Data Distributor Panel	Line Inhibit Module	Incoming Section of the Communications Data Distributor Panel	Matrices V, VI, and VII of Main Switching Unit
Select Oriented Circuits for Users Television/Teletype Interface Area			
Incoming Circuits	Internal Line Assignment Module	Incoming Section of the Communications Data Distributor Panel	Matrix V of Main Switching Unit
Outgoing Circuits	Internal Line Assignment Module	Outgoing Section of the Communications Data Distributor Panel	Matrix XII of Main Switching Unit
Select Oriented Circuits for Computer Area "A"			
Incoming Circuits	Internal Line Assignment Module	Incoming Section of the Communications Data Distributor Panel	Matrix VI of Main Switching Unit
Outgoing Circuits	Internal Line Assignment Module	Outgoing Section of the Communications Data Distributor Panel	Matrix XIII of Main Switching Unit
Select Oriented Circuits for Computer Area "B"			
Incoming Circuits	Internal Line Assignment Module	Incoming Section of the Communications Data Distributor Panel	Matrix VI of Main Switching Unit
Outgoing Circuits	Internal Line Assignment Module	Outgoing Section of the Communications Data Distributor Panel	Matrix XIII of Main Switching Unit
Select Televised Oriented Circuits on Users Television Monitors			
Incoming Circuits	Channel Selector	At Each Users Television Monitor (Not a Part of This Teletype Specification)	Video Switching Unit (Not a Part of This Teletype Subsystem Specification)
Outgoing Circuits	Channel Selector	At Each Users Television Monitor (Not a Part of This Teletype Specification)	Video Switching Unit (Not a Part of This Teletype Subsystem Specification)
Select Oriented Circuits for Secondary Users, DSIF Control Room, and Communications Operations Room			
Incoming Circuits	Selector Box	At Each Receive-Only Page Printer and Each Send-Receive Page Printer Used to Monitor Incoming Circuits	Matrices VII, IV, and I of Main Switching Unit
Outgoing Circuits for One-Way (Transmit Only) Communications	Internal Line Assignment Module	Outgoing Section of the Communications Data Distributor Panel	Matrices XIV, XI, and VIII of Main Switching Unit
Select Oriented Outgoing Circuits for Two-Way (Receive and Transmit) Communications for Operations Room, DSIF Control Room, and Communications Technical Coordinator Panel Area	Internal Line Assignment Module	Outgoing Section of the Communications Data Distributor Panel	Matrices VIII, XI, and X of Main Switching Unit
Select Oriented Incoming Circuits for Communications Technical Coordinator Panel Area	Selector Box	At the Send-Receive Page Printer	Matrix III of Main Switching Unit
Select Area and Display Board Surveillance Telecasts for Users Television Monitors	Channel Selector	At Each Users Television Monitor (Not a Part of This Teletype Subsystem Specification)	Video Switching Unit (Not a Part of This Teletype Subsystem Specification)

DISPLAYS AND INDICATIONS

The Teletype System includes displays and indications necessary for the efficient and effective use of the system consistent with all operational requirements. Other systems (both human and equipment) must be informed of certain status information and of commands directed to these systems in order to assure successful mission accomplishments involving the SFOF. All such dissemination of information directly from the Teletype System to personnel is accomplished through the use of devices defined as displays. All such dissemination of information directly from the Teletype System to other systems or equipment is accomplished through the use of devices defined as indications. Certain displays and indications are not a part of this system but are part of and involved in the teletype interface areas. However, all controls for displays and indications are a part of this system, and, therefore, discussions are directed toward the controls rather than the displays and indications.

The display functions have been arranged into groups according to the display locations and the indication functions have been arranged into groups according to the other systems and equipment which require them. The groups of displays and indications are organized as follows:

a. Displays for Communications Technical Coordinator Panel

b. Displays for Communications Data Distributor Panel

c. Displays for Selector Boxes

d. Displays for Channel Selectors

e. Indications for Communications Status Board

f. Indications for DSIF Control Room Deny Module

g. Indications for Computer Areas

h. Indications for Video Switching Unit

When control signals emanate from another system for transmission to the Teletype System, the originating system provides the required contact closures. In these cases the Teletype System includes the required power supplies. Where control signals emanate from the Teletype System for transmission to another system, the other system provides the required power supplies. In these cases the Teletype System includes the contact closures. For purposes of these definitions only, the Communications Status Board and DSIF Control Room Deny Module are considered to be part of the Teletype System.

All control signals for indications for the Communications Status Board are 6 Volts DC. All other control signals for indications effected by power supplies which are part of the Teletype System and all control signals for displays are 24 Volts DC.

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APPENDIX G - DESIGN SPECIFICATIONS - CLOSED CIRCUIT TV SYSTEM FOR JPL SFOF

1. SCOPE

1.1 This specification establishes the design requirements for an integrated closed circuit TV installation to supplement other communications media in coordinating operational activities within the Space Flight Operation Facility (SFOF). System and equipment functions are defined and described herein to establish the basis upon which detailed proposals are solicited.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification, to the extent specified herein:

SPECIFICATIONS

<u>Jet Propulsion Laboratory</u>

JPL-8900	Environmental Specification; DSIF, Ground Equipment, Assembly Level Test Requirements, Type II.
JPL-8902	General Specification; DSIF, Documentation Requirements.
JPL-20016	General Specification; Workmanship Requirements for Electronic Equipment.
JPL-20025	General Specification; Contractor Quality Control requirements.
JPL-30608	Standard Specification; DSIF, Assembly Identification; Ground Equipment.
JPL-30612	Standard Specification; SFOF Paint Standard.
JPL-30613	Standard Specification; SFOF Engraving Standard
JPL-30280	Standard Specification; SFOF Operational Communications System Installation.

Standard Specification; SFOF Operational Communication System Equipment Racks.

<u>Electronic Industries Association</u>

RS-170	Electrical Performance Standards, Monochrome Television Studio Facilities (Revision TR-135, Nov. 1957)

3. REQUIREMENTS

3.1 <u>Conflicting requirements</u>. Any conflicting requirements arising between this specification and any specification or drawing listed herein shall be referred in writing to the Jet Propulsion Laboratory (JPL), cognizant engineer, for interpretation and clarification.

3.1.1 <u>Requests for deviation</u>. Any deviation from the functional requirements of this specification or from the drawings, specifications, publications, materials and processes specified herein shall be considered a design change or deviation and shall not be allowed except by written authorization from the JPL cognizant engineer.

3.1.2 <u>Alternative proposals</u>. In addition to responding to these specifications as written, bidders may submit bids on alternative proposals which will fulfill the functional requirements outlined herein.

3.2 <u>Materials, parts, and processes</u>. Materials, parts, and processes used in the design, fabrication, and assembly of the products covered by this specification shall conform to the applicable documents specified herein. The contractor's selection shall assure the highest uniform quality and condition of the product, suitable for the intended use, and such selection shall be subject to the approval of the JPL cognizant engineer.

3.2.1 Construction. Construction practices shall be in compliance with the stated design objectives of this specification and representative of the highest quality workmanship as specified in JPL-20016, General Specification, Workmanship Requirements for Electronic Equipment. Systems and components shall be constructed to promote reliability of operation and facilitate maintenance of the equipment.

3.2.1.1 Modularity. Equipment shall be designed to be modular by chassis and/or subchassis to facilitate rapid diagnosis and isolation of trouble conditions, and to minimize system down time.

3.2.1.2 Operational reliability. Reliability of operation shall be stressed throughout the design and manufacture of the equipment. The manufacturer shall employ all methods feasible in the process of manufacture which will assure quality and maximum reliability consistent with the state-of-the-art. In the functional application of parts to equipment circuits, adequate factors of safety shall be provided by suitable deratings from the parts' specification values. Attention shall be given to the effects of temperature and other environmental conditions upon the parts used. Peak voltages and currents during warm-up periods, and transients during operation, shall be considered in the choice of parts. The design shall include all possible features which will result in reliable and stable operation, with reduced requirements for adjustment and alignment, reduced frequency of failure, and reduced requirement for maintenance. The possibility of incorporating self-checking and simplified maintenance techniques shall be carefully considered to reduce the requirement for highly skilled maintenance personnel.

3.2.1.3 Accessibility. The equipment shall be constructed so that it may be installed and serviced with access to all chassis and mechanical assemblies. Easy and ready access shall be provided to the interior parts, terminals, and wiring for adjustment, circuit checking, and removal and replacement of parts. This paragraph need not be applied in the case of special packaging such as potted or hermetically sealed units.

It will, in general, not be acceptable to displace or remove wires, cables, or parts of assemblies in order to gain access to terminals, soldered connections, mounting screws, and the like. When it is not feasible to avoid such construction, prior approval of alternative arrangements must be obtained from the JPL cognizant engineer. In this event, those parts which must be displaced or removed shall be so designed, mounted, and otherwise arranged to facilitate their displacement or removal when necessary.

3.2.1.4 Controls. The values of controls shall be so chosen that normal operation of the controls is obtained without crowding at either end. The tapers of adjustable rheostats and potentiometers shall be so chosen that adjustments are not critical. The controls shall be divided into three categories: front panel, panel screwdriver, and interior.

3.2.1.4.1 Front Panel Controls. Controls that are continually essential to the proper operation of the equipment shall be mounted on the panel and provided with knobs suitable for adjustment. The labels for these controls shall be illuminated where necessary with provisions for adjusting the brightness level.

3.2.1.4.2 Panel Screwdriver Controls. Controls that are occasionally required for proper operation of the unit shall be accessible from the panel and shall be adjustable by means of a screwdriver or similar tool. These controls shall be provided with covers or other suitable protection to prevent inadvertent or careless misadjustment.

3.2.1.4.3 Interior Controls. Controls that are infrequently required for the proper adjustment or operation of the equipment shall not be accessible from the front panel. They shall be accessible when the unit is opened or removed for servicing purposes. These controls shall be provided with locking devices suitable for retaining permanence of adjustment. In the case of circuit trimmers, padder adjustments, and the like, this requirement will be considered to be met when the adjustments are secured by friction in a manner assuring permanence of adjustment under the shock and vibration conditions encountered in normal use.

3.2.2 Component selection. The contractor shall utilize components of a demonstrated reliability. Standard RETMA parts shall be used whenever possible. Electronic parts shall be suitably derated consistent with the requirements of weight, size and reliability. The degree of derating for each part shall be determined by the contractor subject to approval of the JPL cognizant engineer.

3.2.3 Identification. Equipment shall be identified in accordance with JPL-30608, Standard Specification, DSIF, Assembly Identification, Ground Equipment. Parts, units, sub-units, and components shall be suitably labelled in a manner consistent with the supplier's designation system. All parts having the same part number shall be directly interchangeable, both electrically and mechanically.

3.2.3.1 Method of Marking. Identification markings shall be permanent and legible. The markings on plastic or metallic materials shall be effected by stamping, engraving, stenciling with smudgeproof ink covered with a coat of clear lacquer, or silk screening. Foilcals and fotofoils with heat or solvent-activated adhesive backing may be used.

3.2.3.2 Rubber Stamping and Decalcomanias. Rubber stamping shall not be used. Foilcals and fotofoils may be used with standard commercial material and bonding characteristics.

3.2.3.3 Transformer Marking. All transformers shall be provided with a diagram stenciled on the case or printed on a plate attached to the case. This diagram shall show internal connections of the transformer and voltages or impedances between terminals. Wherever possible, this diagram shall be easily read when the transformer is installed in the equipment.

3.2.3.4 Terminal Designations. Terminal numbering shall be as recommended and furnished by the contractor. All terminals for connection to transmission lines shall be marked with the nominal characteristic impedance of the line.

3.2.3.5 Wire Identification. Conductors in interchassis cable wiring shall be identified by use of colored insulation or jacket; by color tracer on the insulation or jacket; by printed letters, printed numbers, or both; by color-coated braids; or by combinations of these or similar methods. Color-coding of wires, where used, will be as defined by the manufacturer. Identification of individual conductors is not required on internal chassis wiring.

3.2.3.6 Function Identification. The function of each control and indicator shall be identified by symbols and abbreviations. The identification shall be adjacent to the control and indicator wherever possible.

3.2.4 Wire and Cabling.

3.2.4.1 Wiring. Point-to-point intra-chassis wiring will be permissible. All inter-chassis wiring and, where desirable, intra-chassis wiring shall be harnessed and laced or otherwise constrained with suitable means.

3.2.4.2 Hookup Wiring.

a. Conductors with 19 strands shall be used wherever practicable. All conductors shall be of such cross section and temper as to provide ample and safe current-carrying capacity and mechanical strength.

b. Whenever practicable and consistent with accessibility and weight constraints, the following wire sizes shall be used:

    1) Flexed inner wiring, no smaller than AWG 22.

    2) Rigid inner wiring, no smaller than AWG 24.

c. All wiring in the equipment shall, insofar as it is practical, be distinctly color-coded or marked in order to facilitate testing and the locations of faults.

3.2.4.3 Printed Wiring. Printed wiring shall be in accordance with the best commercial practices.

3.2.4.4 Cables. Interunit cabling shall, whenever possible, utilize standard commercial cables. Cable specifications for each special cable type shall be defined by the manufacturer.

3.2.4.5 Cable Jamming. Special provisions shall be included to prevent cable jamming when the chassis are placed in servicing positions or returned to normal positions.

3.2.4.6 Cable Entrance Plates. The location of removable cable entrance plates shall be defined by the manufacturer.

3.2.4.7 Video Cables. Video cables shall be RG59/U with appropriate BNC series quarter-turn locking connectors.

3.2.5 Maintenance.

3.2.5.1 Overload Protection. Protective devices shall be provided within the equipment for primary circuits and such other circuits as are required for protecting the equipment from damage due to conditions such as overload and excessive heating. All parts which are likely to carry an overload (due to malfunction of circuits, poor adjustments, component casualty, or other damaging effects) shall be designed to accommodate such an overload. Where this is impracticable, circuit breakers, relays, fuses, or other devices shall be included to protect the affected parts. The protective devices of each branch of the power input shall be centralized and easily accessible for maintenance purposes.

3.2.5.2 Interlocks. Interlocks are not required. High voltage danger identification and special mounting location, cages, or other suitable protection shall be employed for voltages over 300 volts.

3.2.5.3 Test Points. The number and type of test points shall be compatible with test instrumentation (built-in or otherwise) that is available at the place of system use, or at the maintenance or repair activity. Test points shall be compatible with the system circuitry to minimize the possible loss of performance occasioned by their use. Sufficient test points shall be made available to facilitate the location of the most probable circuit malfunctions which may reasonably be expected to occur within the equipment. For the most part, however, the test points shall be used to provide access for measurement of general parameters, and significant data interpretation. Significant voltages, currents, and waveforms shall be measurable at test points so that alignment procedures and the determination of circuit faults may be carried out expeditiously.

3.2.6 Environmental Control. The equipment shall be provided with apertures, louvers, and other openings to permit ventilating and heat removal where necessary. Cooling shall be accomplished by moving air over the heat-generating components. Heat removal will be accomplished by air exhaust to the surrounding area. Sufficient air circulation shall be provided to prevent the failure of parts due to excessive heating. If blowers are necessary, they shall be driven by a brushless type a-c motor utilizing flameproof insulation on their power leads. A-c motors, requiring brushes for starting purposes only, will be acceptable. Where forced-air cooling is used, ducts or baffles shall also be used, where necessary, to direct air flow toward parts dissipating large amounts of heat. The ventilation air provided will be filtered, conditioned air and essentially free of dirt and dust.

3.2.7 Finish. Front panels and exposed metal parts shall be finished in accordance with JPL-30612 Standard Specification, SFOF Paint Standard. Paint for this purpose will be furnished by JPL.

3.3 General Requirements. The equipment shall meet the general requirements of this specification and the reference specifications noted herein. The design requirements noted below shall be duly considered during all phases of equipment design and fabrication.

3.3.1 Power Source. The system shall perform in accordance with the applicable requirements of this specification when supplied with an input power source of 115 volts, ± 10%, 60 cycles per second, ± 5% alternating current (a-c).

3.3.2 Enclosures.

3.3.2.1 User Equipment. Equipment provided for utilization by the normal user shall be designed to mount in consoles, or similar type enclosures to be specified and supplied by JPL.

3.3.2.2 Centralized Control and Test Equipment. Equipment provided for utilization by technical and maintenance personnel shall be designed to mount on standard 19" relay rack mounting rails furnished by JPL as part of their standard enclosures. These enclosures are delineated in JPL-   Standard Specification, SFOF Operational Communication System Equipment Racks.

3.3.3 Environment. Environmental conditions to which this equipment will be subjected and under which it will be expected to perform in accordance with this specification are defined in JPL-8900, Environmental Specification, DSIF, Ground Equipment, Assembly Level Test Requirements, Type II.

3.4 Design Objectives.

(a) Reliability. Reliability is considered to be of prime importance and can be achieved only through careful and thorough analysis, design, development, fabrication, testing, installation, and checkout.

(b) Flexibility. A design inherently capable of accommodating a variety of system configurations and expansion to twice initial size is extremely important.

(c) Maintainability. Equipment and system design shall stress means to minimize the need for periodic routine maintenance as a requirement for satisfactory and reliable operation. Provisions shall be incorporated to facilitate early recognition and minimum-time correction of potential or actual trouble conditions.

(d) Economy. Full realization of the above design objectives within the present state-of-the-art shall represent the principal requirements for the system. Reduction of first costs and continuing operating and maintenance expenses is a major secondary consideration.

3.5 System Design.

3.5.1 Functional Description. The closed circuit TV system will be comprised of several subordinate systems to be utilized in the following applications: general area surveillance, teletype data distribution, and special purpose. These systems shall be so integrated that any of a number of monitors shall have access to the video output from any one of a number of cameras on a random demand basis.

3.5.1.1 Area Surveillance. Sixteen (16) cameras shall be provided to present a general view of each of the major operational areas within the SFOF for utilization by the Test Director and others as required to maintain cognizance and coordination of the activities in support of current operations. These cameras shall be placed at strategic locations throughout the building as indicated in Table 1 and generally as shown on the attached floor plans. These cameras shall be mounted in a fixed position to encompass the area of primary interest and activity within the field of view from that location. Each camera will be equipped with a fixed-focus, wide angle lens.

3.5.1.2 Teletype Data Distribution. Provisions for up to twenty-one (21) cameras shall be included in the Communications Teletype Room in the basement. These cameras (15 of which will be provided initially) will each be mounted above an associated teletype page printer in such fashion as to observe a six-inch length of standard teletype printout (approximately 8" wide) as it is being typed. Cameras for this application shall be fixed in position and equipped with suitable lenses.

Table G-1 Closed Circuit TV Equipment Requirements and User Access

Users' Monitors	Application	TTY – Receivers	TTY – Transmitters	Opnl. Communications	Telemetry Monitor	DPS Area	Comm. Cntl. Room	DSIF Cntl. Room	FPAA	SPAA	SSAA #1	SSAA #2	Operations Area	External	TV Room
Cameras: Type		Fixed													Movable
Lens		Special		Wide-Angle											Zoom
	# RQD	12	3	1	1	3	1	1	2	2	1	1	2	1	1
SSAA Director Console	1	x									x	x	x		
SPAA Director Console	1	x								x			x		
FPAA Director Console	1	x							x				x		
SSAA Representatives Console	2	x									x	x			
SPAA Representative Console	2	x								x					
FPAA Representative Console	2	x							x						
SFOF Opns. Mgr. Console	2	x	x			x	x		x	x	x	x			
DSIF Opns. Mgr. Console	2	x	x		x		x	x	x	x	x	x			
Test Director Console #1	2	x	x						x	x	x	x		x	
Ass't Test Director Console #1	2	x							x	x	x	x			
Test Director Console #2	2	x	x						x	x	x	x		x	
Ass't Test Director Console #2	2	x							x	x	x	x			
DSIF Control Console #1	2	x	x		x		x								
DSIF Control Console #2	2	x	x		x		x								
DSIF Control Console #3	2	x	x		x		x								
Communications Control Console	2	x	x	x		x		x	x	x	x	x	x		
Communications Tech. Coor. Console	2	x	x												
Communications Distribution Console	2	x		x											
Data Processing System Ctl. Console	2	x	x			x	x		x	x	x	x			
Standby Room	2												x		
2nd Floor Conference Rooms	4	x	x										x		
Operations Analysis Room	2								x	x	x	x	x		
Gallery	2	x	x											x	
TV Tech. Control	1	x	x	x	x	x	x	x	x	x	x	x	x	x	x
External	2												x		x

3.5.1.3 Special Purpose. One special camera equipped for complete remote control shall be fitted with a zoom lens and installed on a pan and tilt head in the TV Room. A pan, tilt, and zoom control panel for this camera will be provided in the TV Tech Control area. A second control panel will be furnished for future installation at a selected monitor position.

3.5.1.4 Sync Generator. A master sync generator shall be rack mounted in the TV Tech Control area. The sync generator shall incorporate complete backup facilities with either manual or automatic changeover between the two units in the event of failure of either. The sync signal shall be normal EIA as defined in EIA Standard RS-170 and compatible with Commercial Television Broadcast practices.

The system shall incorporate provisions for the addition of sync delay networks and Special Effects generators to permit superimposed image and split-field presentations at a future time.

3.5.1.5 Switching and Video Distribution. Central switching facilities, video amplification, and isolation shall be provided as required such that each TV monitor shall have essentially independent access to the video output signal from any camera. This equipment shall be rack mounted in the TV Tech Control area and shall incorporate the capability for restricting operational access of the individual monitors to particular camera outputs on a completely flexible pre-assigned basis. This pre-assignment shall be accomplished in some easily modified manner, such as patchboard or pinboard. The picture to be viewed at a monitor shall be selectable on demand from its pre-assigned available choices by means of pushbuttons at the monitor location.

3.5.1.6 Broadcast TV Receiver. The system shall include the capability of receiving and disseminating commercial TV telecasts, one channel at a time. The broadcast receiver installation shall include a suitable antenna array mounted on the roof of the SFOF capable of satisfactory reception of all local VHF TV stations.

The audio and video outputs shall terminate on jack strips in the TV Tech Control area where they shall be available for patching into the Public Address and the Closed Circuit TV systems, respectively. The audio output of the receiver shall be capable of driving a balanced 600 ohm load at a zero dbm level, and shall be monitored by a panel-mounted speaker.

3.5.2 Main Distribution Frame. The Main Distribution Frame (MDF) to be installed by others in the Communications Terminal Room shall provide terminal appearances for all closed circuit TV video, camera control, and switching control leads entering or leaving the SFOF.

3.5.2.1 Video. A special section of the MDF shall be equipped to terminate and cross-connect video cable runs to other on-Lab locations. Ten (10) appearances of this type will be adequate.

3.5.2.2 Control Leads. Leads to permit the complete control (including pan, tilt, and zoom) of a remote camera, as well as switching system control leads, and lamp leads to indicate teletype monitor line availability, shall appear on the MDF for each monitor position external to the SFOF. 2500 such appearances will be adequate.

3.5.3 Patching Facilities. Provision shall be made for patching video cables and control leads at system nodes appropriate to enhancing over-all accessibility and flexibility.

3.5.3.1 Video. Video coaxial cables shall enter and leave the switching system via jackfields providing both bridging and looped through jack access to the signal channel. These jackfields shall be so designed that normal operation will obtain with no patch cords inserted. In emergencies, appropriate patching shall facilitate alteration of system configuration, isolation of and substitution for malfunctioning system components, and capability to accommodate other foreseeable contingencies with minimum degradation of service.

3.5.3.2 Switching Control. The TV Switching Matrix shall include the capability of providing each monitor access to every camera. Operationally, however, only those crosspoints whose control leads are connected through to the monitor position can be activated. Patching (plugboard or pinboard) provisions in TV Tech Control will permit this access to be set up and modified easily to fulfill mission requirements.

3.5.3.3 Camera Remote Control. Cables from TV Tech Control to all cameras and to all monitors shall include leads suitable for the remote control of pan, tilt, and zoom functions. These leads shall be terminated in patching (or strapping) facilities in TV Tech Control to permit later addition of and required flexibility in the administration of this capability. Initially, only TV Tech Control will possess the means for such control.

3.5.4 Test Facilities. The bidder shall recommend and supply special rack-mounted test equipment, system monitor and checkout provisions, and equipment spares required to ensure a 0.99 confidence level of conformance with the reliability standards specified in Paragraph 3.9.2. Test equipment may include pattern generators, sweep generators, wave form monitors, and/or others suitable for both on-line trouble isolation and detailed off-line test, repair and replacement of faulty components.

Camera and monitor video cables shall be installed to a patch panel in the Closed Circuit TV Repair Area in the basement to provide access to and from the video switching system for diagnostic and checkout purposes.

3.5.5 Monitor Facilities. Provisions shall be made in TV Tech Control for a Master Video Monitor having unrestricted access to all closed circuit TV camera outputs. This monitor will be utilized for preventive and corrective maintenance to detect and diagnose trouble conditions and serve as a tool in their correction.

3.5.6 Recording. There are no requirements for recording closed circuit TV video at the present time.

3.5.7 Switching and Distribution. A central switching and distribution system shall provide the means for connecting any monitor to any camera.

3.5.7.1 Video Distribution. Video distribution shall be implemented such that any of the possible viewers may switch onto or off the output from a single camera indiscriminately in any combination without the generation of disturbing transients and without noticeably affecting the quality of the picture.

3.5.7.2 Video Switching. The video switching system shall be initially equivalent in size to a 40 x 50 matrix. Thus it will accommodate up to 40 direct camera inputs, and will provide outputs to drive up to 50 monitors, each of which will have pushbutton control of its own matrix crosspoints. This matrix shall be modularly expandable to an additional 50% in each direction (60 inputs and 75 outputs) with a minimum of added expense and inconvenience. Later expansion into an integrated system of 120 inputs x 150 outputs shall be possible essentially by duplicating equipment and connections of the expanded installation.

The Video Switching Matrix will receive control signals in the form of the momentary operation of isolated contacts, one set for each crosspoint. The matrix shall be designed to respond by releasing any previously established connection to the input of the associated monitor, and by operating and holding the newly requested crosspoint connection, in that order.

Associated with each crosspoint shall be provided an electrically isolated set of contacts to be utilized to light a lamp at the user's module indicating the particular crosspoint that is operated. In addition, twelve (12) crosspoints shall include a second set of isolated contacts for use with circuitry in the Teletype Switching matrix to coordinate the assignment of camera/printer combinations for the closed circuit TV distribution of teletype data. The TV supplier shall furnish twelve completely separate and isolated power supplies for use in conjunction with this latter set of crosspoint contacts to control the switching of camera/printer pairs. These power supplies each shall have sufficient capacity to operate up to 75 crosspoints simultaneously in the TV Switching Matrix.

3.5.7.3 Switching Access. Capability of any monitor position to operate its associated matrix crosspoints will be restricted at Tech Control. Only those crosspoints having leads activated in accordance with Paragraph 3.5.3.2 will be locally operable.

3.5.8 Operations Control. Operations control will be exercised by the viewers through pushbuttons at the monitor positions. Selection of any TV channel is accomplished merely by depressing the appropriate button, provided access has been established in Tech Control.

Initial set up and periodic monitoring of fixed camera positioning, optical, and electrical adjustments are the responsibility of Tech Control. Remote control of the movable camera will be provided initially to Tech Control, with the facility to transfer this capability to selected users at a future time.

3.5.9 User Modules. A user module shall include four sub-modules:

1) A picture tube for displaying the picture,
2) A monitor chassis with power supply and circuitry for driving the picture tube,
3) A control panel to permit individual control and adjustment of the desired picture, and
4) A Channel Selector panel enabling the viewer to select the desired channel for display.

These sub-modules shall be packaged to permit separate mounting in the user consoles to be supplied by JPL.

3.5.9.1 Picture Tube. The picture tube shall be a fourteen (14) inch rectangular cathode ray tube which shall provide a black and white picture of sufficient brilliance to be seen easily in a maximum ambient light level of 100 foot-candles. Treatment to reduce surface reflections shall be incorporated in the tube face and/or the protective face plate.

3.5.9.2 Monitor Chassis. The monitor chassis will include all power supply, sync, sweep, and video circuitry required to drive the picture tube. In addition, it shall incorporate on a recessed panel, the following infrequently used controls: focus, horizontal centering, vertical centering, horizontal hold, and vertical hold.

3.5.9.3 Control Panel. The control panel shall provide front panel access to the more often used controls: on-off switch with pilot light, brightness, and contrast.

3.5.9.4 Channel Selector. The Channel Selector will be furnished by the supplier of the teletype system. It consists of a panel of illuminated pushbuttons by which the viewer selects the desired camera output for viewing on his monitor. Depression of a channel selector button causes the momentary operation of an electrically isolated set of contacts which, in turn, closes the proper crosspoint in the TV Switching Matrix to connect the output of the desired camera to the input of the user's monitor.

3.5.10 Cameras. Cameras shall be supplied and installed in accordance with the information given in Table I, Fig. G-1, and the building floor plans, (Fig. G-2,3,4).

3.5.10.1 Camera Controls. Camera electrical adjustments shall be primarily remote controlled from the TV Tech Control area. The camera unit itself, however, shall be provided with its own on-off switch, pilot light, and video gain control, easily accessible without dismounting the camera.

Figure G-1 Closed Circuit Television System

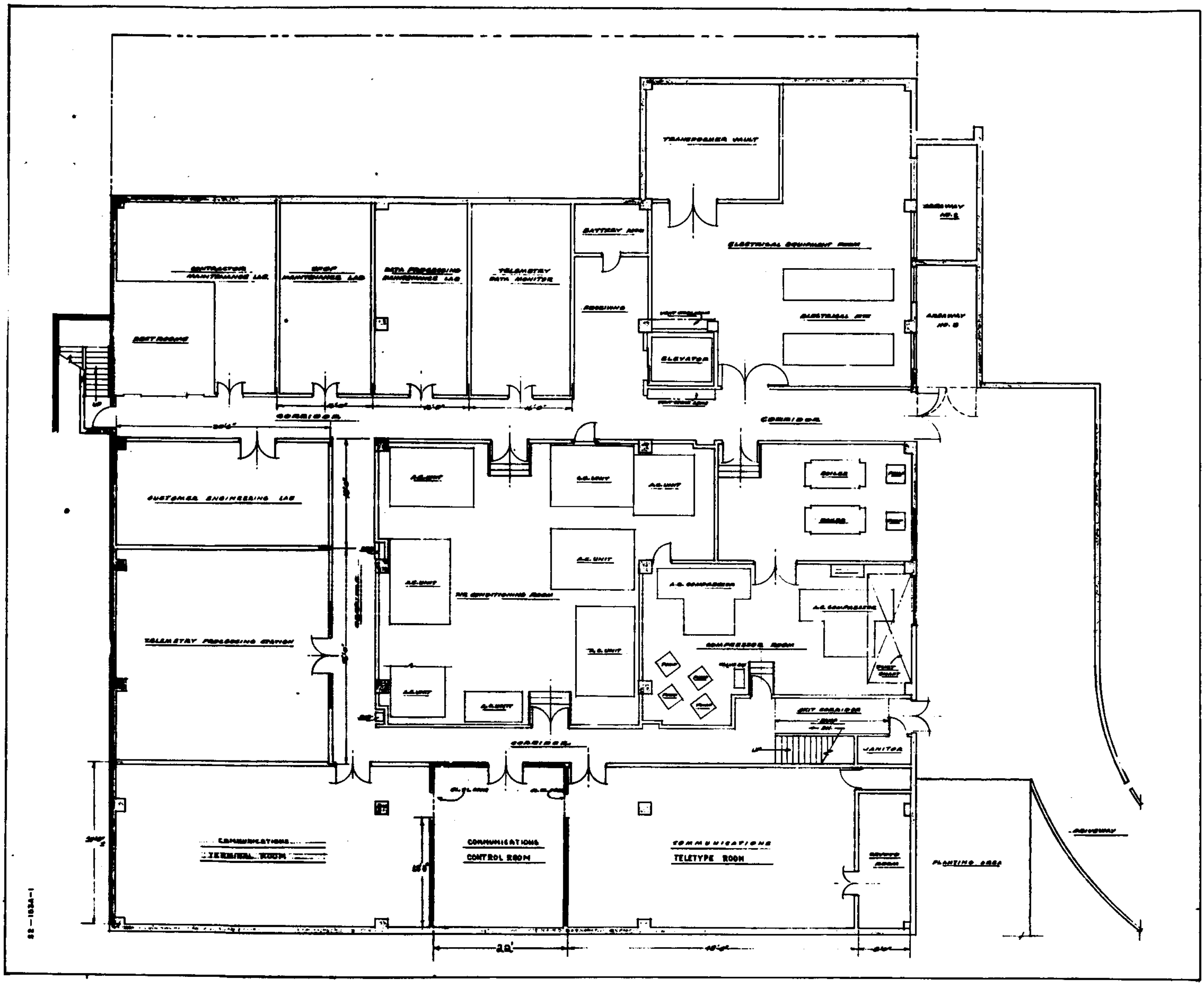

Figure G-2 SFOF Floor Plan Basement

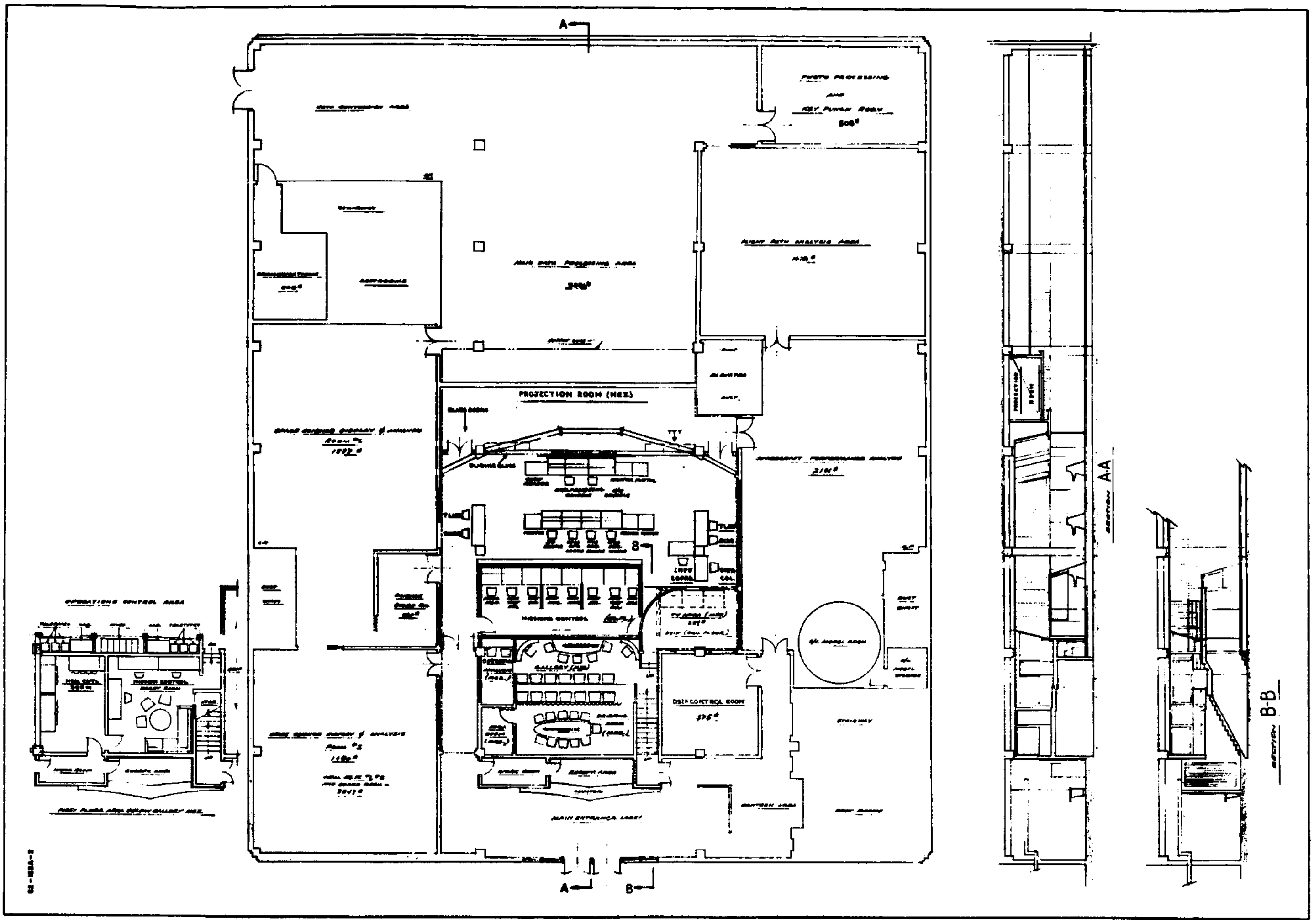

Figure G-3 SFOF Floor Plan Main Floor

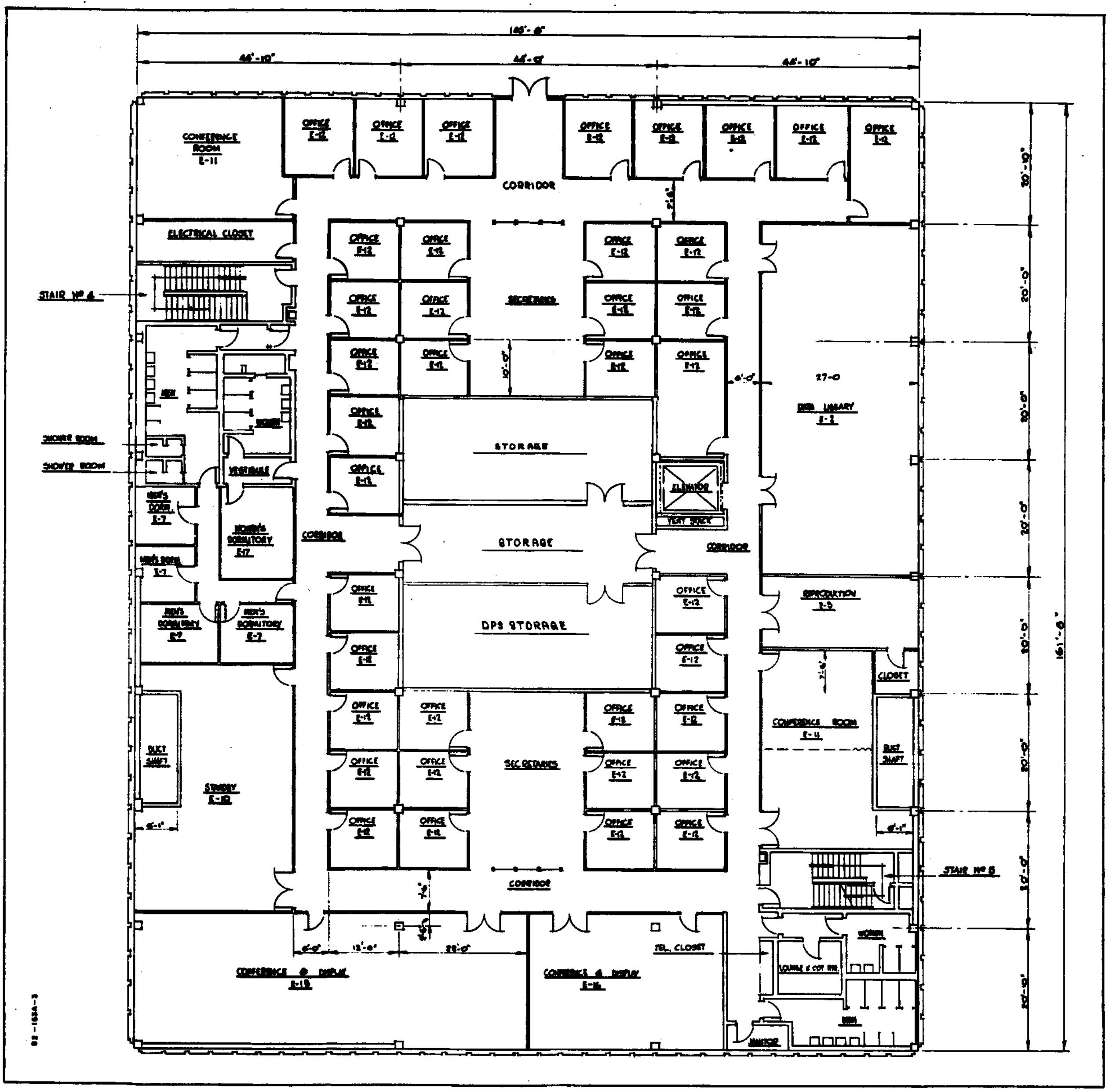

Figure G-4 SFOF Floor Plan Main Floor

3.5.10.2 Lenses. All cameras shall be equipped with selected 16 mm camera lenses with standard "C" mounting. The vendor shall determine the lens requirements for all areas in the SFOF.

3.5.10.3 Mounting. The camera base shall provide a ¼"-20 mount to fit standard 16 mm motion picture camera pan and tilt heads. All cameras shall be mounted on such heads unless otherwise specified.

3.5.11 Communications Center. The Communications Center will furnish the technical control, monitoring, and maintenance functions required for the proper operation of the closed circuit TV system.

Each camera shall have its own camera control unit rack mounted in the TV Tech Control area. This unit will permit the remote control of camera power and all required electrical adjustments such that, in conjunction with the Master Video Monitor, each camera may be set up and periodically checked by TV Tech Control from the Communications Terminal Room.

TV Tech Control will also be responsible for establishing and modifying the patching connections providing access of the different monitor positions to their associated switching matrix crosspoints and to the remote pan, tilt, and zoom controls for the movable camera. The "patching up" of special system configurations as required for optimum operations in emergency or other extraordinary situations will be accomplished from the Communications Center.

3.6 Electrical Performance.

3.6.1 System. The performance of the over-all system shall conform to the following standards, and shall meet or exceed the following requirements.

3.6.1.1 Scanning Parameters. Scanning parameters shall be:

Field/frame rate: 60/30 per second with 2:1 interlace

Lines/frame: 525

Aspect ratio: 4:3

3.6.1.2 Resolution. Minimum resolution shall be as follows when measured on a normal system monitor in accordance with EIA Standard RS-170:

	Center	Corner
Horizontal, or line, direction	650	450 lines/picture height
Vertical, or field, direction	450	300 lines/picture height

3.6.1.3 Geometric Distortion. No picture element shall be displaced by more than ± 2% of the picture height from its true position.

3.6.1.4 Video Transmission.

Bandwidth: 8 megacycles ± 1 db, minimum

Aperture correction: Phase distortionless, variable ±8db correction at 8 megacycles.

High frequency peaking: Adjustable, independent of aperture correction.

3.6.1.5 Sensitivity. The system shall provide a usable picture with 1 foot-candle average illumination on the subject using an F/1.5 camera lens.

3.6.1.6 Dynamic Range. All ten shades of gray shall be visible when viewing an EIA test pattern with 20 foot-candles of illumination and using an F/1.5 lens stopped down to F/5.6.

3.6.1.7 Shading and Spurious Signals. With a flat 1 foot-candle of illumination on a completely white scene, shading and other similar spurious signals shall have an amplitude level no greater than:

20 db below mean peak white signal amplitude, synchronized, and 40 db below mean peak white signal amplitude, nonsynchronized with the scanning frequencies.

3.6.1.8 Radio Frequency Interference. Careful consideration shall be given by the supplier to the inclusion of adequate measures to minimize system susceptibility to the disturbing effects of external radio frequency interference. Conversely, the level of any internally generated radio frequencies shall be so low as to cause no objectionable interference with any other system in the SFOF.

3.6.2 Camera.

3.6.2.1 Video Output. The camera shall have a minimum composite video output of 1.4 volt peak-to-peak, black negative, into a 75 ohm load with 10 foot-candles average illumination at the vidicon.

3.6.2.2 Vidicon Protection. A circuit shall be provided to protect the vidicon in the event of interrupted horizontal or vertical sweep. This circuit shall provide indication of loss of either or both sweeps by means of a light on the associated camera control panel in TV Tech Control.

3.6.2.3 Automatic Light Compensation. Automatic light compensation shall provide constant picture contrast over an illumination variation up to 4000:1.

3.6.3 Monitor.

3.6.3.1 Input. The monitor shall have a high impedance bridging input arranged for looped through connection or termination with a switched 75 ohm internal resistor.

3.6.3.2 Gain. Monitor video gain shall be 46 db, minimum.

3.6.3.3 Bandwidth. Monitor video bandwidth shall be flat $\pm$ 1 db to 10 megacycles, minimum.

3.6.4 Video Switching Matrix. The TV Switching Matrix shall have a frequency response flat $\pm$ 1 db to 20 Megacycles, minimum, with a maximum differential phase shift of 5 degrees.

3.7 Installation. The bidder shall install and complete a satisfactory operational checkout of all equipment supplied in response to these specifications. Installation shall be in accordance with JPL- 30280, Standard Specification, SFOF Operational Communications System Installation, JPL-20016 General Specification, Workmanship Requirements for Electronic Equipment, and with pertinent electrical codes and industry accepted practice under the supervision of the JPL cognizant engineer or his designated representative.

3.8 Documentation. Documentation of the equipment and its installation shall be as provided in JPL-8902, General Specification, DSIF, Documentation Requirements, and shall be delivered to JPL within 10 days following the completion of installation.

3.9 Reliability. System reliability requirements are of prime importance and the supplier shall be prepared to demonstrate, document, and otherwise guarantee that his equipment does in fact meet or exceed the standards established below and in the associated reliability specification ______________. Operational reliability performance standards specified below are predicated upon the availability of average trained maintenance personnel having three months' experience with the system.

3.9.1 The over-all system shall have a probability of 0.99 that it will be completely and continuously operable for a period of 24 hours.

3.9.2 The closed circuit TV system shall have a Mean Down Time (MDT) of 15 minutes, with a probability of 0.99 that any Down Time will not exceed 30 minutes.

3.9.3 Camera, monitor, and test equipment shall have a Mean Time to Repair (MTTR) of 60 minutes, with a probability of 0.99 that any Time to Repair (TTR) will not exceed 90 minutes.

3.9.4 Switching equipment shall have an MTTR of 10 minutes, with a probability of 0.99 that any TTR will not exceed 15 minutes.

4. Quality Assurance Provisions.

4.1 Unless otherwise specified herein, the supplier is responsible for the performance of all inspection requirements prior to submission for JPL inspection and acceptance. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to JPL. Inspection records of the examinations and tests shall be kept complete and available to JPL as specified in the contract or order.

4.2 Pre-delivery Inspection. The system covered by this specification shall be partially mocked up at the supplier's plant and demonstrated to the satisfaction of the JPL cognizant engineer or his representative to be in accordance with the requirements of this specification. A list of the tests to be performed and the test methods shall be approved by the JPL cognizant engineer.

5. Preparation for Delivery.

6. Notes.

6.1 JPL will furnish fifteen General Electric Model 4TE9B3 Cameras. Twelve of these cameras will be used in the system and three will be used as spares. The supplier will be responsible for any modifications required to insure compatibility of these cameras with his equipment.

6.2 The supplier shall furnish:

a) System diagrams indicating unit model numbers, cable and connector type numbers, cable lengths, and interconnection of all units.

b) Schematic diagrams of all units, published specification literature, and installation and maintenance manuals.

c) Cost of manufacturer's field personnel for installation supervision and complete system checkout to assure that the system is operating in accordance with the specifications herein.

d) Cost of on-site and/or factory training of JPL personnel in proper operation and maintenance of equipment.

e) Cost of an unconditional parts and labor warrantee for a one-year period.

f) Description of facilities available for field service to comply with warrantee.

g) Detailed list of all deviations to the specification. All modifications to standard equipment necessary to meet specifications shall be explained fully and accompanied by modified schematic diagrams.

JPL-SFOF COMMUNICATIONS STUDY – PHASE I FINAL REPORT

APPENDIX H – DESIGN SPECIFICATIONS

PAGING AND PROGRAM DISTRIBUTION SUBSYSTEM FOR JPL SFOF

1. SCOPE

1.1 This specification establishes the design requirements for a combination paging and program distribution sound system within the SFOF.

2. APPLICABLE DOCUMENTS

3. REQUIREMENTS

3.1 Conflicting Requirements. – Any conflicting requirements arising between this specification and any specifications or drawing listed herein shall be referred in writing to the Jet Propulsion Laboratory (JPL), cognizant engineer, for interpretation and clarification.

3.1.1 Requests for Deviation. – Any deviation from the functional requirements of this specification or from the drawings, specifications, publications, materials and processes specified herein shall be considered a design change or deviation and shall not be allowed except by written authorization from the JPL cognizant engineer.

3.1.2 Alternative Proposals. – In addition to responding to these specifications as written, bidders are encouraged to submit bids on alternative proposals which will fulfill the functional requirements outlined herein.

3.2 Materials, Parts, and Processes. – Materials, parts, and processes used in the design, fabrication, and assembly of the products covered by this specification shall conform to the applicable documents specified herein. The contractor's selection shall assure the highest uniform quality and condition of the product, suitable for the intended use, and such selection shall be subject to the approval of the JPL cognizant engineer.

3.2.1 Packaging of Components. – JPL specification 30234 shall be used as a guide for the electronic packaging of components and equipment subject to the following modifications:

> Central control and test equipment shall be mounted in standard 19-inch relay racks in the Communications Terminal Room in the basement of the SFOF. Where appropriate, the individual chasses, or the entire rack shall be enclosed to protect the equipment and the operating personnel. Adequate provision for ventilation will be incorporated.

Equipment shall be designed to be modular by chassis and/or subchassis to facilitate rapid diagnosis and isolation of trouble conditions, and to minimize system down time during critical phases of a mission. The bidder shall recommend and supply adequate spares of a special nature which he deems desirable in ensuring a high probability of continuing high-quality system performance on a long term basis.

3.2.2 Component Selection. — The contractor shall utilize components of a demonstrated reliability. Parts listed in JPL Specification 20061 shall be used whenever possible. If for any reason it becomes necessary to use a part that is not approved, the contractor shall obtain written approval from the JPL cognizant engineer. Electronic parts shall be suitably derated consistent with the requirements of weight, size, and reliability. The degree of derating for each part shall be determined by the contractor subject to approval of the JPL engineer.

3.2.3 Reference Symbol Designations for Component Parts and Subunits.— Markings on parts and subunits shall be as specified by the JPL cognizant engineer and applicable JPL drawings.

3.2.4 Wire (Hook-up). —

a. Conductors with 19 strands shall be used wherever practicable. All conductors shall be of such cross section and temper as to provide ample and safe current-carrying capacity and mechanical strength.

b. Whenever practicable and consistent with accessibility and weight constraints, the following wire sizes shall be used:

   1) Flexed inner wiring, no smaller than AWG 22

   2) Rigid inner wiring, no smaller than AWG 24.

c. All wiring in the equipment shall insofar as it is practical, be distinctly color-coded or marked in order to facilitate testing and the locations of faults.

3.2.5 Dissimilar Metals. — The use of dissimilar metals in contact, as defined in Military Specification MIL-F-14072, pertaining to intermetallic contact, shall be avoided wherever practicable.

3.2.6 Convenience. — Easy and ready access shall be provided to the interior parts, terminals, and wiring for adjustment, circuit checking, and removal and replacement of parts. This paragraph need not be applied in the case of special packaging such as potted or hermetically sealed units. It will not be acceptable to displace or remove wires, cables, parts of assemblies in order to gain access to terminals, soldered connections, mounting screws and the like. When it is not feasible to avoid such construction, those parts which must be displaced or removed shall be so designed, mounted and otherwise arranged to facilitate their displacement or removal when necessary. If it is necessary to displace some other part in order to check or remove a given part, the latter shall be wired and mounted so that it can be sufficiently moved without being disconnected from its circuit.

3.3 Design Objectives. – The public address subsystem shall be designed for optimum operation in accordance with the following relative priority considerations:

(a) Reliability. – Reliability is considered to be of prime importance and can be achieved only through careful and thorough analysis, design, development, fabrication, testing, installation, and checkout.

(b) Flexibility. – A design inherently capable of accommodating a variety of system configurations and expansion to twice initial size is extremely important.

(c) Maintainability. – System and equipment design shall stress provisions to facilitate early recognition and minimum-time correction of potential or actual trouble conditions.

(d) Economy. – Full realization of the above design objectives within the present state of the art shall represent the principal requirement. First cost and anticipated continuing expense is a major secondary consideration.

3.4 System Design. –

3.4.1 Functional Description. – The paging and program distribution subsystem to be installed in the SFOF will be a low-level sound system with a sufficient number of speakers provided to assure adequate sound coverage throughout the building. This system will perform the dual function of paging and of distributing program information of general interest to selected areas within the building. Reference Figure H-1.

The equipment comprising the sound system will be subdivided into eight categories:

(1) Communications

(2) Data Processing

(3) DSIF

(4) Flight Path Analysis

(5) Spacecraft Performance

(6) Space Science

(7) Other

(8) Special

Figure H-1 Paging and Program Distribution System corresponding to the six operationally functional areas within the SFOF, plus other areas not a part of a specific operational entity, and, finally, special users throughout the SFOF which overlap the above categories.

Each category will be provided its own power amplifier, rack mounted in the Communications Terminal Room. Each amplifier will be sufficiently derated to permit delivery of audio output power to at least 125 percent of initial requirements. This will allow moderate speaker reallocation to conform to projected functional area reassignment during SFOF evolution. Access to the input terminals of each amplifier will be established by Communications Control. Speakers will be connected to the appropriate amplifier in accordance with their location and application in the building.

3.4.1.1 Paging System. — The paging system will be utilized to alert specific individuals in special situations, and to coordinate and direct general SFOF activities during nonstandard conditions. Amplifiers in the operationally functional categories (1) through (6) above will be utilized for "local" paging service in each area on an independent basis. All of these amplifiers, plus the amplifier for category (7), will be employed in concert for general SFOF-wide paging as required.

When connected for paging service by Communications Control, input access to these amplifiers will be provided via the operational telephone switching system under user control.

Paging system speakers on the first floor shall be mounted in the ceiling in a 12 inch by 12 inch grid pattern (150 speakers total). Paging speakers in the basement and on the second floor shall be provided as shown on the layout diagram. These speakers will have screwdriver adjust volume controls mounted integrally in the speaker housing for initial system setup, but they shall be essentially inaccessible to the normal user.

3.4.1.2 Program Distribution System. — The program distribution system will provide general dissemination of activity on any desired conference net, information of common interest, background music, etc. as desired. Equipment in "Special" category (8) above will be utilized for this service, also under control of Communications Control.

Thirty-five (35) program distribution speakers will be furnished, 18 suitable for ceiling mounting, and 17 suitable for wall mounting. Actual location of these speakers will be determined at a later date. Each speaker will have its own volume control which can be remoted for wall mounting. Volume adjustment of these speakers will be a local option.

3.4.2 Main Distribution Frame. — All lines associated with the sound system which enter and leave the SFOF shall do so via the main distribution frame where they shall appear for identification, cross-connect, test, and maintenance as required. Provision for the appearance of ten (10) such lines will be adequate.

3.4.3 Patching Facilities. — Provision shall be included at appropriate system modes for patching necessary to maximize overall system maintainability and flexibility. In particular, amplifier inputs and outputs shall be accessible by jackfields including both bridging and normalled jacks.

Paging speaker leads shall be grouped by rooms within the SFOF. This grouping shall be accomplished on terminal strips at the room location so as to facilitate speaker rearrangement as necessary to accommodate moderate changes in interior wall locations. Each room group will be separately wired to the Tech Control area where it shall have the capability of being patched (by strapping or patchboard) in accordance with functional room assignment.

All program distribution speakers shall be wired home to Tech Control where they shall be individually accessible for patching in a similar fashion.

3.4.4 Test Facilities. — No special test equipment is required for the sound system. The bidder shall, however, recommend and supply spare modular components as required to ensure a 0.99 confidence level of conformance with the reliability standards specified in Paragraph 3.8.2.

3.4.5 Monitor Facilities. — Means shall be included to permit individual monitoring of all amplifier inputs and outputs.

3.4.6 Recording. — Voice recording capability provided as an adjunct to the operational telephone system will have access to all SFOF paging system input circuits via the voice switching system and may be utilized as desired for this application. No additional recording capability is required.

3.4.7 Switching and Distribution. — The input of each sound system amplifier shall be accessible by means of a six-pushbutton switch, rack mounted in the Tech Control area. These switches shall be momentary contact type with the associated switching connections held electrically in the switching matrix. These connections shall be electrically interlocked such that only one of the six is activated at any time, and that one will be indicated by illuminating the corresponding pushbutton.

The six input buttons will be able to select between:

(1) Off — Amplifier B+ power control

(2) SFOF — General operational paging

(3) Lab — JPL paging

(4) Misc. — Green or other conference net as desired

(5) Misc. — As required

(6) Radio — Program, background music, etc.

as directed by the Communications Coordinator.

With input connections (3) through (6) above, the system shall permit local page messages to override the normal input to the paging amplifiers on the operational areas. With SFOF input connection (2), the normal input (operational page messages for general SFOF dissemination) will override local paging.

The SFOF input to the sound system will appear in the voice switching system as a restricted stored number available only to the users listed below:

SSAA Director's Console*	SFOF Operations Manager Console
SPAA Director's Console*	DSIF Operations Manager Console*
FPAA Director's Console *	Test Director Console No. 1
SSAA Representative's Console*	Test Director Console No. 2
SPAA Representative's Console*	Lobby Desk
FPAA Representative's Console*	Talker Desk No. 1
Communications Control Console*	Talker Desk No. 2
Data Processing System Control Console*	

Those users indicated by * will also have access to a similar restricted stored number which will switch their voice line to the input to the amplifier corresponding to the functional area with which they are associated. This connection will be available at all times through the voice switching system, regardless of the input switching configuration established in Communications Control. As described above, then, local page will override any other input signal with input connections (3) through (6), or, in turn, will itself be overridden in the event of a general page with input connection (2).

In addition to the power amplifiers specified in Paragraph 3.4.1, preamplifiers shall be provided as required to permit independent level adjustment and control for each of the eight categories of sound coverage. A line amplifier shall also be supplied to facilitate connecting any desired output from the sound system into the voice switching system for wider distribution.

3.4.8 Operations Control. — Primary operations control of the sound system will be exercised by the Tech Control personnel in the Communications Control area, under direction of the Communications Coordinator. Secondary operations control, in the case of the paging system, will be effected by console operators and other specified users, by means of the voice switching system and stored number buttons on their voice modules.

3.4.9 User Modules. — Paging system input will be accomplished through the operational telephone switching system via the telephone voice module, using the normal headset or other optional input equipment to be furnished by others. In general, two stored number buttons will appear on the panel:

(1) "Local Page" — for announcements of utility only to the area under the cognizance of the console originating the message, and

(2) "General Page" — for SFOF-wide announcements.

Operation of the "Local Page" button will switch the console transmitter to the corresponding functional area amplifier input, and the operator at the console may make announcements to his own area. Operation of the "General Page" button will connect the console transmitter to the SFOF input line to the sound system, which will enable a general announcement through all amplifiers with the SFOF input switch connection established.

Utilization of the voice switching system to provide input connection to the paging amplifiers avoids complications which might arise due to inadvertent simultaneous requests for paging service by multiple users having common equipment access. In such a case, the switching system will automatically connect one and return a busy signal to the others.

3.4.10 Communications Center. — The Communications Center will provide the technical control, monitoring, and maintenance functions required for the proper operation of the sound system. In addition, it will furnish the primary operational control of the input connections.

Tech Control will be responsible for the initial setup and preservation of the volume levels throughout the SFOF, for all preventive and corrective maintenance, and for patching and switching as required to produce special system configurations needed to achieve optimum operations in emergency or other extraordinary situations.

3.5 Environment. — This system shall operate normally in ambient temperatures between -10 degrees and 50 degrees Centigrade, and at relative humidities up to 95 percent.

3.6 Installation. — The bidder shall install and conduct a complete operational checkout of all equipment supplied in response to these specifications. Installation shall be in accordance with pertinent electrical codes and industry accepted practice under the supervision of Hughes Aircraft Company and JPL. Checkout shall include not only complete electrical test but also preliminary operational instruction of designated JPL personnel.

3.7 Documentation. — Complete documentation including, but not restricted to, system block diagrams, schematic and wiring diagrams, installation and interconnection drawings, operating instructions, troubleshooting and maintenance procedures, and spare parts lists shall be delivered to JPL within 30 days following the completion of installation.

3.8 Reliability. — System reliability requirements are of prime importance and the supplier shall be prepared to demonstrate, document, and otherwise guarantee that his equipment does in fact meet or exceed the standards established below and in Reference Specification.

3.8.1 The overall sound system shall have a probability of 0.99 that it will be completely and continuously operable for a period of 100 hours.

3.8.2 The sound system shall have a Mean Down Time (MDT) of 5 minutes, with a probability of 0.99 that any Down Time (DT) will not exceed seven minutes.

3.8.3 Individual items of equipment shall have a Mean Time To Repair (MTTR) of 30 minutes, with a probability of 0.99 that any Time To Repair (TTR) will not exceed 45 minutes.

APPENDIX I - DETAIL SPECIFICATIONS
SFOF — GOLDSTONE MICROWAVE MULTIPLEX SYSTEM

1.0 SCOPE

1.1 This specification covers the requirements of the equipment necessary to multiplex a number of voice-bandwidth channels and a single broadband channel over a microwave radio channel of a Western Union type MLD-4 system.

1.2 Design objectives: The multiplex equipment shall be designed for optimum operation in accordance with the following relative priority list:

(a) Reliability
(b) Frequency Stability
(c) Delay Distortion
(d) Maintainability

2.0 APPLICABLE DOCUMENTS

3.0 REQUIREMENTS

3.1 Definitions: The subject equipment is considered to consist of three subsystems as follows:

3.1.1 Voice Channel Multiplex: The voice channel multiplex will accept voice frequency signals from data, teletype, and voice sources and process these into composite signals suitable for full duplex communication over microwave facilities.

3.1.2 Signaling Subsystem: The signaling system will provide the necessary circuitry for signaling and supervision as well as the required interface equipment for connecting to external voice bandwidth circuits.

3.1.3 Baseband Channel: The baseband channel will provide the necessary circuitry for connecting a broadband signal of specified characteristics into the microwave system.

3.2 Voice Channel Multiplex

3.2.1 Channel Capacity

3.2.1.1 Initial: The equipment shall provide an initial capability of twenty-four (24) voice-frequency communication channels.

3.2.1.2 Ultimate: The basic equipment design shall provide a modular expansion pattern capable of meeting an anticipated future requirement of approximately fifty-seven (57) voice-frequency channels within a baseband spectrum of 12 to 240 KC's.

3.2.2 Type: This equipment shall utilize an amplitude-modulated, single-sideband, suppressed-carrier modulation plan and shall compose the baseband signal by frequency division.

3.2.3 Frequency Allocation: The frequency allocation plan of this equipment shall conform to CCITT patterns at the group, supergroup, and line frequencies. The initial twenty-four (24) channel subsystem shall utilize a baseband spectrum between 140 and 240 KC's.

3.2.4 Processing Capability: The equipment shall have a demonstrated capability to accept and process voice bandwidth analog and digital information. An optional feature shall provide the flexibility of combining nominal 4 KC channels into wider band channels.

3.2.5 Carrier Frequency Synchronization

3.2.5.1 Type: A pilot tone shall be directly derived from the master oscillator of a terminal designated the "Master Terminal." This pilot tone shall be injected into the composite transmitted signal of the "Master Terminal" without frequency conversion. At the "Slave Terminal", the master oscillator and all carrier frequencies shall be phase synchronized to the received pilot tone. A fail-safe feature shall be included to insure that the "Slave Terminal" master oscillator will lock on the last received pilot frequency without hunting when, for any reason, reception of the synchronizing pilot tone is interrupted.

3.2.5.2 Stabilization Time: The requirement for stability with synchronization (3.2.5.4) shall be achieved within a sixty (60) minute initial starting time.

3.2.5.3 Master Terminal Stability: The master terminal shall exhibit a master oscillator frequency stability of ± 1 part per miooion during a thirty (30) day period following a sixty (60) day period of continuous operation.

3.2.5.4 Subsystem Stability: The back-to-back frequency translation error of a 1000 cps test tone in any channel shall be zero (0) with pilot synchronization and shall be less than 5 cps for a thirty (30) day period without pilot synchronization and without adjustment for the worst channel of the subsystem.

3.2.5.5 Phase Jitter: The drop-to-drop phase jitter for a 1000 cps test tone in any channel shall not exceed ± 10° when measured with the terminals connected back-to-back.

3.2.6 Spurious Output: The initial twenty-four (24) channel subsystem shall utilize a baseband spectrum between 140 and 240 KC's (3.2.3). Transmitted energy falling outside this spectrum shall have a total energy, within any 4 KC slot, not less than 55 db below the per-channel transmitted test tone level. Discrete tones falling outside this spectrum shall not exceed a level 60 db below the per-channel transmitted test tone level.

3.2.7 Operating Levels and Impedances

3.2.7.1 Receiving Baseband: The multiplex terminals shall be capable of the specified performance when the receiving baseband terminals are connected to a 75-OHM unbalanced source of composite signal having a level of two (2) volts peak-to-peak. The receiving baseband level into the multiplex terminals shall be adjustable in 1 db steps over a ± 10 db range.

3.2.7.2 Transmitting Baseband: The multiplex terminals shall be capable of delivering a composite signal on a 75-OHM unbalanced transmitting baseband line having a level of two (2) volts peak-to-peak that is adjustable in 1 db steps over a ± 10 db range.

3.2.8 Voice Channel Requirements

3.2.8.1 Frequency Response: The back-to-back frequency response of any channel shall exhibit a maximum variation of 1.5 db over the band 300 to 3450 cps referred to 1000 cps test tone.

3.2.8.2 Envelope Delay Distortion: The back-to-back envelope delay distortion of any channel shall not exceed 300 microseconds for any two frequencies between 800 and 3100 cps, or 150 microseconds for any two frequencies between 1000 and 2500 cps, including equalization.

3.2.8.3 Noise and Unintelligible Crosstalk: The vendor shall present suitable documentation of test results on a 600-channel system connected back-to-back to demonstrate:

(a) An idle channel noise level not exceeding 15 dba (F1A) on an idle system, and
(b) An idle channel noise plus unintelligible crosstalk level not exceeding 23 dba (F1A), referred to the zero transmission level point, with the system fully loaded with voice, data, or a combination of these, and
(c) The test results, on the same basis, that may be anticipated for the initial 24-channel subsystem.

3.2.8.4 Intelligible Crosstalk: The vendor shall present suitable documentation of test results on a 600-channel system connected back-to-back to demonstrate an effective far-end crosstalk attenuation of not less than 65 db and an effective near-end crosstalk attenuation of not less than 50 db.

3.2.8.5 Harmonic Distortion: With the two 24-channel terminals connected back-to-back and the 4-wire voice frequency levels set to the maximum specified, the total harmonic distortion in any channel shall not exceed a level 40 db down from any fundamental test tone frequency within the channel pass-band.

3.2.8.6 Intermodulation Distortion: When any two frequencies (A & B) within the channel pass-band are applied to the input of any channel at a level of 0 db 0, the 2A 2B products shall not exceed a level of -40 db 0 and the A ± B products shall not exceed a level of -34 db 0, measured at the appropriate receiving drop.

3.2.8.7 Carrier Leak: The measured carrier leak levels shall not exceed the following maximum values:

(a) Channel Carriers ..... - 25 db 0.
(b) Pregroup Carriers .... - 25 db 0.
(c) Group Carriers .... - 30 db 0.

3.2.8.8 Level Stability: A test tone transmitted in any channel at the specified level shall exhibit a short-term level variation of less than ± 1.0 db due to:

(a) A received baseband level variation of ± 6 db.
(b) An ambient temperature range of 0° to 50° C.
(c) A.C. supply voltage variations of ± 10% from nominal.

3.2.8.9 Limiting Action: With a test tone injected at the zero transmission level point, the channel gain reduction as a function of test tone level shall be:

(a) 0.5 db or less for a + 3.5 dbm input, and
(b) 5.0 db or more for a + 12.0 dbm input.

3.2.8.10 Operating Levels and Impedances

3.2.8.10.1 Transmitting: The 4-wire channel input level shall be -16 dbm minimum to) dbm maximum in 600-OHMs balanced.

3.2.8.10.2 Receiving: The 4-wire channel output level shall be 0 dbm minimum to +7 dbm maximum in 600-OHMs balanced.

3.3 Signaling Subsystem

3.3.1 Type: The signaling equipment may be external to the multiplex channelizing equipment. The signaling equipment modules shall provide for CCITT compatible out-of-band "E" and "M" signaling, but optional equipment shall be available for ringdown applications. For the purposes of this specification, 2-wire hybrids are considered an optional portion of the signaling module.

3.3.2 Quantity: Twelve (12) signaling modules will be associated with voice communication circuits. These shall be equipped for "E" and "M" signaling and for 2-wire 600-OHM balanced voice channel terminations.

Six (6) signaling modules will be used for data transmission and miscellaneous signaling. These shall be equipped for "E" and "M" signaling and for 4-wire 600-OHM balanced voice channel terminations.

Six (6) signaling modules shall be provided and used for data circuits that do not initially require signaling. These modules shall provide for the addition of "E" and "M" signaling at some future time. The module shall afford 4-wire 600-OHM balanced voice channel terminations.

3.3.3 Options: Modules provided for "E" and "M" signaling shall be capable of signaling against ground or battery of either polarity. The "E" lead shall be rated at not less than 0.1 ampere average at 48 volts.

The 2-wire to 4-wire hybrids may be optionally contained in the channel or signaling modules. These shall be coil hybrids with compromise balancing networks.

3.3.4 Signaling Speed: The subsystem modules shall be capable of any signaling speed in the range of 0 to 14 pps.

3.3.4 Pulse Width Distortion: Pulse width distortion shall be limited to a maximum value of 1.5 missiseconds for changes in speech path transmission equivalent to ± 3.0 db referred to the nominal voltage at 14 pps with a 60/40 space/mark ratio.

3.3.6 Dial Distortion: For a back-to-back measurement, with an "M" lead impulsed at 10 pps with a make ratio of 33°/o, the code distortion at the associated distant "E" lead shall be within ± 5°/o for a transmission level variation of ± 3.0 db and a signaling frequency variation of ± 10 cps.

3.3.7 Dialing Noise: Under the test conditions specified for dial distortion (3.3.7), the weighted noise generated at the receiving output of either adjacent channel shall not exceed a level 60 db below test tone level.

3.4 Baseband Channel Characteristics

3.4.1 General Requirement: A suitable means shall be incorporated into the transmit and receive baseband sections of each multiplex terminal to provide filtered access to the otherwise unused 0.3 to 130 KC spectrum of the Western Union transmission equipment.

3.4.2 Frequency Response: The circuitry used to couple the broadband equipment to the baseband lines shall have a 3 db bandwidth of 0.3 to 100 KC's and a maximum variation in response of ± 1.0 db within this band.

3.4.3 Impedances: Provisions shall be made to match connected broadband equipment at 72 OHMs unbalanced.

3.5 Test Facilities

3.5.1 Test Equipment: Each terminal equipment complex shall contain an integrated test equipment facility that is specifically designed for and is completely capable of performing the following functions:

(a) Complete end-to-end alignment.
(b) In-service measurement of pilot signal levels at each modulation step.
(c) In-service measurement of carrier frequency outputs of carrier supplies and amplifiers.
(d) Provide a source of test tone for measurement of transmission levels.
(e) Provide a means of isolating system malfunctions to a major assembly or subassembly.
(f) Provide for measurement and adjustment of signaling circuits.
(g) Shall include a narrow-band high-impedance frequency selective voltmeter of suitable frequency range.

3.5.2 Patching Facilities: Both normal and bridging jacks shall be provided at the drop and equipment sides of all voice frequency and signaling circuits.

3.5.3 Failure Alarm Subsystem: Each equipment module or modem that is common to more than one voice frequency channel shall have its performance monitored by an alarm system. The alarm subsystem shall monitor the output of all power supplies, carrier frequency equipment transmit/receive path amplifiers, group pilots, and synchronizing pilots. The monitoring circuitry shall be "fail safe" in all cases. A visual and audible indication of malfunction shall be an integral part of each terminal equipment complex and provisions shall be made for duplication of alarm indication at a remote point.

3.6 Prime Power Requirements

3.6.1 Type: The multiplex terminal equipments shall be designed to utilize power from a 120-volt, 60-cycle, single-phase source.

3.6.2 Regulation: Specified performance shall be realized when operating from a power source that is regulated within ± 10%, 108-132 volts.

3.6.3 Stability: Specified performance shall be realized when operating from a power source having a frequency stability of ± 5%, 57-63 cps.

3.7 Mechanical Design

3.7.1 Mounting: All equipment shall be installed in Stone & Smith cabinets with rear doors. The cabinet and all exposed panel and equipment faces shall be finished with paint to be furnished by JPL. The equipment shall be free standing without the use of floor bolts or top bracing.

3.7.2 Cable Access: The entry of external cables from either overhead racks or from floor ducts shall be optional.

3.7.3 Front Access: All test points, adjustment controls, terminal boards, and plug-in subassemblies shall be easily accessible from the front of the equipment racks. It shall be possible to withdraw and/or tip up any module for access during maintenance procedures and without interruption of service.

3.7.4 Packaging: The basic equipment design shall evidence a maximum application of current techniques in the employment of printed circuitry. Equipment modules and subassemblies shall be designed for plug-in installation in equipment shelves. It shall be a design objective to maximize the use of identical and interchangeable modules and to minimize the number of types.

3.8 Reliability Criteria

3.8.1 General Requirement: These requirements are intended to insure the procurement of equipments having the maximum reliability and availability that can be achieved in the field of voice multiplex design. The basic equipment design shall make possible the detection and isolation of any malfunction and the replacement of any defective subassembly in as short a period of time as possible. The vendor shall submit suitable documentation to demonstrate:

(a) A mean time to replacement (MTTR) of a subassembly not exceeding fifteen (15) minutes; with a probability of 0.999 that no MTTR will exceed twenty (20) minutes.

(b) A mean time between failure (MTBF) of five hundred (500) hours at a 0.90 confidence level for a period of continous operation of two thousand (2000) hours.

(c) A system point availability of 0.995 for 50% of the required channel capacity for a period of at least two thousand (2000) hours under actual field conditions.

(d) A system point availability of 0.999 for 100% of the required channel capacity for a period of at least two thousand (2000) hours under actual field conditions.

3.8.2 <u>Active Components</u>: All active circuitry shall use solid state devices to the exclusion of vacuum tubes.

3.8.3 <u>Passive Components</u>: All passive components shall be RETMA types of proven reliability and shall be generously derated.

3.8.4 <u>Redundancy</u>: All active circuitry and/or subassemblies that are common to the operation of more than twelve (12) voice frequency channels shall be completely redundant. Such redundancy shall be accomplished only with passive devices and sparing techniques using active switching or patching shall not be acceptable.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 <u>Classification of Tests</u>: The subject equipment shall be acceptance tested to demonstrate compliance with the technical requirements of this specification (3.0).

4.2 <u>Acceptance Tests</u>: The subsystem shall be subjected to acceptance testing at the contractor's facility and again, following installation, at JPL facilities. Both series of tests shall be observed by cognizant JPL engineers.

4.3 <u>Test Conditions</u>: Acceptance tests at the contractor's facility shall be conducted on two fully operational multiplex terminals connected back-to-back.

Acceptance tests at the JPL facilities shall be conducted on two fully operational multiplex terminals operating full-duplex over the Western Union type MLD-4 microwave system provided for this purpose.

4.4 <u>Test Methods</u>: The contractor shall prepare test procedures for each test to be required. All test procedures will be required to carry the written approval of the cognizant JPL engineer before performance of tests.

4.5 <u>Test Equipment</u>: The contractor shall propose (4.4) and provide all test equipment required in the performance of acceptance tests.

4.6 <u>Tests</u>

4.6.1 <u>Initial Acceptance Tests</u>: The following tests shall be performed at the contractor's facility as a prerequisite to type acceptance and approval for delivery:

4.6.1.1 <u>Synchronization - Type</u>: Demonstrate compliance with requirements (3.2.5.1) for fail-safe and non-hunting features upon loss of the pilot. Conformance with subsystem stability criteria (3.2.5.4) without synchronizing pilot shall be considered adequate.

4.6.1.2 <u>Stabilization Time</u>: Demonstrate attainment of stability criteria (3.2.5.4) within the specified initial starting time (3.2.5.2).

4.6.1.3 <u>Spurious Output</u>: Demonstrate compliance with the requirements (3.2.6) for the specified extremes of levels (3.2.7).

4.6.1.4 <u>Frequency Response</u>: Demonstrate a frequency response within the specified limits (3.2.8.1) on the lowest and highest frequency channels.

4.6.1.5 Delay Distortion: Demonstrate compliance with the requirements (3.2.8.2) using the lowest and highest frequency channels.

4.6.1.6 Harmonic Distortion: Demonstrate compliance with the requirement (3.2.8.5) using the lowest and highest frequency channels.

4.6.1.7 Intermodulation Distortion: Demonstrate compliance with the requirements (3.2.8.6) using the lowest and highest frequency channels.

4.6.1.8 Carrier Leak: Demonstrate compliance with the requirements (3.2.8.7) using the lowest and highest frequency channels.

4.6.1.9 Level Stability: Demonstrate the required level stability (3.2.8.8) using the lowest and highest frequency channels and for all combinations of the varying parameters specified. Level stability as a function of ambient temperature may be optionally documented, rather than demonstrated, if a prototype equipment has been previously tested under the requirements of MIL-E-4970A or the equivalent.

4.6.1.10 Limiting Action: Demonstrate compliance with the requirements (3.2.8.9) using the lowest and highest frequency channels.

4.6.1.11 Signaling Speed: Demonstrate compliance with the requirement (3.3.4) using a representative channel.

4.6.1.12 Pulse Width Distortion: Demonstrate compliance with the requirement (3.3.4) using a representative channel.

4.6.1.13 Dial Distortion: Demonstrate compliance with the requirement (3.3.6) using a representative channel.

4.6.1.14 Dialing Noise: Demonstrate compliance with the requirement (3.3.7) using a representative channel and a battery voltage of 48 VDC.

4.6.1.15 Broadband Channel Characteristics: Test to demonstrate that the requirements (3.4.2) are met or exceeded.

4.6.1.16 Failure Alarms: Demonstrate the proper operation of all specified failure alarm circuitry (3.5.3).

4.6.2 Final Acceptance Tests: The following tests shall be performed at the JPL facilities following installation as a prerequisite to formal acceptance of the operating subsystem:

4.6.2.1 Master Terminal Stability: Demonstrate compliance with the requirement (3.2.5.3).

4.6.2.2 Subsystem Stability: Demonstrate compliance with the requirements (3.2.5.4).

4.6.2.3 Phase Jitter: Demonstrate compliance with the requirement (3.2.5.5) using pilot synchronization.

4.6.2.4 Spurious Output: Demonstrate compliance with the requirement (3.2.6) with the subsystem fully loaded.

4.6.2.5 Delay Distortion: Demonstrate compliance with the requirements (3.2.8.2) using the lowest and highest frequency channels.

4.6.2.6 Intermodulation Distortion: Demonstrate compliance with the requirements (3.2.8.6) using the lowest and highest frequency channels and with baseband levels adjusted to optimum for the associated microwave system.

4.6.2.7 Broadband Channel Characteristics: Demonstrate an end-to-end frequency response meeting or exceeding the requirements (3.4.2) and an end-to-end envelope delay distortion meeting or exceeding the requirements (3.4.4).

4.6.2.8 Test Facilities: Accomplish initial subsystem alignment using only the specified test equipment (3.5.1) as a demonstration of the adequacy of this test equipment.

4.7 Rejection and Resubmittal: Equipments not meeting the minimum specified requirements (3.0) shall be rejected and returned to the contractor. Before resubmittal, full particulars concerning the previous rejection and action taken to correct the defects shall be forwarded to JPL.

5.0 PREPARATION FOR DELIVERY

Not applicable.

6.0 MISCELLANEOUS REQUIREMENTS

6.1 Preparation of Test Plans: It shall be the responsibility of the contractor to prepare complete procedures for the required acceptance tests (4.0).

6.2 Interface Coordination: These equipments will interface with the Western Union MLD-4 system at baseband and with internal voice-frequency circuits at distribution frames. It shall be an integral part of the contractor's responsibility to accomplish the necessary compatibility at these interfaces.

6.3 Installation: The contractor shall be responsible for any necessary packaging and transportation of the subject equipment to JPL facilities; for a complete installation within the defined interfaces; and for initial system alignment and checkout.

6.4 Technical Documentation: Not less than 15 days prior to equipment delivery, the contractor shall supply JPL with preliminary documentation. Such preliminary documentation shall consist of shcematic diagrams, chassis drawings, photographs, and detailed working parts lists relating symbolic nomenclature used on the schematics directly to type, value, and the manufacturer's part designation. This documentation shall define the design status of the equipment and may incorporate "redlined" corrections and changes where necessary.

Not more than 30 days following final acceptance of the installation, the contractor shall supply JPL with final documentation. This documentation shall reflect the exact characteristics of the equipment and installation at the time of final acceptance. No changes shall be indicated in the final documentation which have not been physically incorporated and tested at the time of final acceptance.

Minor changes resulting from continuing test procedures may be provided as supplementary documentation and shall be provided in each case no later than 30 days following the date of actual change or modification.

6.5 Spare Parts List: The final documentation shall include a list of spare parts. The list shall include plug-in components, such as fuses, transistors, etc.; nonstandard piece parts, such as special hardware, relays, inductors, etc. The quantities of these spares shall be calculated on the following basis:

Less than 4 units in service = 100% spares

4 to 10 units in service = 4 spares

More than 10 units in service = 10 spares

The list shall also include equipment modules and modems on the following basis:

One spare at each terminal of each unit that is common to five or more voice-frequency channels.

One spare or 5% of the total (whichever is greater) at each terminal of each unit that is common to four or less voice-frequency channels.

JPL-SFOF COMMUNICATIONS STUDY – PHASE I FINAL REPORT

APPENDIX J – DETAIL SPECIFICATION SPACE FLIGHT OPERATIONS FACILITY GOLDSTONE TELETYPE MULTIPLEX

1. SCOPE

1.1 This specification covers the requirements of the equipment necessary to multiplex a number of teletype communication circuits over a number of voice-frequency multiplex channels between the Space Flight Operations Facility at Pasadena and the Deep Space Instrumentation Facility at Goldstone.

1.2 Design Objectives. – The teletype multiplex equipment shall be designed for optimum operation in accordance with the following relative priority list:

(a) Reliability

(b) Stability

(c) Flexibility

(d) Maintainability.

2. APPLICABLE DOCUMENTS

See also the "Statement of Work; Space Flight Operations Facility, Goldstone Teletype Multiplex."

3. REQUIREMENTS

3.1 Definitions. – The subject equipments are considered to consist of four subsystems as follows:

3.1.1 Loop Equipment. – The loop equipment shall perform the required modulation/demodulation processing between D-C teletype loops and frequency shift keyed subcarriers in the voice-frequency range.

3.1.2 Line Equipment. – The line equipment shall perform the required modulation/demodulation processing between the loop equipments and the voice-bandwidth communication facilities.

3.1.3 Alarm System. – The alarm system shall monitor certain specified operating parameters to indicate malfunction of failure.

3.1.4 Test Facility. – The test facility shall provide the means for maintenance of optimum performance.

3.2 Loop Equipment

3.2.1 Initial Capacity. — The equipment shall provide an initial capacity of eight (8) standard loops in each of two (2) carrier-derived voice-frequency channels.

3.2.2 Carrier Frequency Spacing. — The initial configuration shall provide a minimum of 240 cps spacing between subcarrier mean frequencies within a voice-frequency band.

3.2.3 Carrier Frequencies. — The eight (8) subcarrier mean frequencies in a voice-frequency channel (3.2.1) shall be duplicated in the second voice-frequency channel for flexibility.

3.2.4 Ultimate Capacity. — The basic equipment design and frequency allocation plan shall permit modular expansion to an ultimzte capacity of not less than twenty-four (24) standard loops in each of two (2) carrier-derived voice-frequency channels using a minimum of 120 cps spacing between subcarrier mean frequencies.

3.2.5 Type. — This equipment shall utilize frequency shift keying of subcarriers within the voice-frequency range.

3.2.6 Deviation. — Mark/space keying shall result in an instantaneous deviation of a subcarrier frequency not exceeding ± 30 cps.

3.2.7 Information Rate. — The equipment shall be capable of all transmission speeds up to and including 100 wpm.

3.2.8 Bias Distortion. — The bias distortion introduced by this equipment shall not exceed 5 percent at 100 wpm.

3.2.9 Bias Variation. — The maximum bias variation versus subcarrier mean frequency deviation shall not exceed 2 percent per cycle in any channel.

3.2.10 Bias Correction. — The equipment shall be capable of bias correction up to 25 percent marking or spacing.

3.2.11 Loop Options. — The initial equipment configuration shall be equipped to operate half-duplex at 60 ma neutral at 130 volts.

3.2.12 Loop Option Flexibility. — The basic loop equipment design shall provide for possible adaption to future loop requirements, such as:

(a) Half-duplex, 20 to 70 ma at 48, 60 or 130 volts

(b) Full-duplex, 20 to 70 ma at 48, 60 or 130 volts

(c) One-way polar, ± 30 to 40 ma at 48, 60 or 130 volts

(d) Two-path polar, ± 30 to 40 ma at 48, 60 or 130 volts

(e) W.E. type 2 hub, full or half duplex

(f) Inverse neutral hub

(g) Neutral sending — polar receiving

(h) TWX service with supervision

(i) TELEX service for exchange switching

(j) Back-to-back operation with 43A terminal, including supervision, on a full or half duplex basis.

3.3 Line Equipment

3.3.1 Initial Capacity. — Two (2) sets of line equipment shall be provided to permit the interconnection of eight (8) loop equipments with each of two (2) carrier-derived voice-frequency channels (3.2.1).

3.3.2 Ultimate Capacity. — Each line equipment channel shall be capable of future expansion to a minimum of twenty-four (24) loop equipments (3.2.4).

3.3.3 Impedance. — The line equipments shall interconnect with the associated carrier-derived voice-frequency channels at 600 ohms balanced and on a 4-wire basis.

3.3.4 Levels. — The line equipments shall be adjustable for and shall provide specified operation with per channel transmitting and receiving levels between -40 dbm and -15 dbm.

3.4 Alarm System

3.4.1 Functions. — The alarm system shall monitor the output of all power supplies, transmission/receive path amplifiers, and the status of the associated carrier-derived voice-frequency channels. A threshold circuit shall be provided in both the transmitting and receiving paths of each subcarrier to detect the presence or absence of subcarrier. The monitoring and alarm circuitry shall be "fail safe." Wherever electronic redundancy is provided, each of the duplicate equipments shall be monitored individually.

3.4.2 Supervision. — Each malfunction (3.4.1) shall cause the operation of visual and audible indications. Major and minor alarms shall be visually indicated by a multicolor lamp display. Provisions shall be made for the silencing of the audible alarm during a malfunction of long duration. The visual indicators shall not indicate normal operation while a malfunction persists.

3.4.3 Remote Supervision. — All supervisory functions (3.4.2) shall be made available at terminals for connection to remote indicators.

3.5 Test Facility

3.5.1 Test Equipment. — Each terminal equipment complex shall contain an integrated test equipment facility that is specifically designed for an is completely capable of performing the following functions:

(a) Measurement of loop currents

(b) Measurement of subcarrier levels and frequencies

(c) Measurement of distortion and determination of type and probable source.

3.5.2 Patching Facilities. — An integral part of each terminal equipment complex shall be a patching facility affording the following:

(a) Access to all test equipment (3.5.1)

(b) Loop supervision jacks (16 loops)

(c) Four-wire carrier equipment and line (2 circuits)

(d) Spare four-wire carrier equipment and line (2 circuits)

(e) Loop battery test

(f) Test ground

(g) Four-jack test jack circuit (2 circuits)

(h) Voice order wire (2 circuits)

3.6 Prime Power Requirements

3.6.1 Type. — The equipment shall be designed to utilize power from a 120 volt, 60 cycle, single-phase source.

3.6.2 Regulation. — Specified performance shall be realized when operating from a power source that is regulated within ±10 percent, 108-132 volts.

3.6.3 Stability. — Specified performance shall be realized when operating from a power source having a frequency stability within ±5 percent, 57-63 cps.

3.7 Mechanical Design

3.7.1 Mounting. — All equipment shall be installed in standard 19-inch four-post open-frame racks having a maximum height of 8 feet and a maximum depth of 30 inches.

3.7.2 Cable Access. — The entry of external cables from either overhead racks or from floor ducts shall be optional.

3.7.3 Front Access. — All test points, adjustment controls, terminal boards, and plug-in subassemblies shall be easily accessible from the front of the equipment racks.

3.7.4 Packaging. — The basic equipment design shall evidence a maximum application of current techniques in the employment of printed circuitry. Equipment modules and subassemblies shall be designed for plug-in installation in equipment shelves. It shall be a design objective to maximize the use of identical and interchangeable modules and to minimize the number of types.

3.8 Reliability Criteria.

3.8.1 General Requirement. — These requirements are intended to provide the maximum of reliability, availability, and maintainability that can be attained with modern teletype multiplex equipments. The basic equipment design shall facilitate the detection of failure, isolation of the defective subassembly, and replacement with an identical spare unit. The vendor shall submit supporting documentation to demonstrate an expected mean down time of 5 minutes; with a probability of 0.999 that no down time will exceed 7 minutes.

The vendor shall also submit supporting documentation to demonstrate an expected availability of 100 percent of the specified traffic handling capability (3.2.1) for more than 99.9 percent of the time during a 2000-hour period of continuous operation.

3.8.2 Active Components. — All active circuity shall use solid state devices to the exclusion of vacuum tubes.

3.8.3 Redundancy. — Redundancy techniques may be employed to meet the reliability requirements (3.8.1). Such redundancy shall be accomplished only with passive devices and sparing techniques using active switching or patching shall not be acceptable.

4. QUALITY ASSURANCE PROVISIONS

4.1 Classification of Tests. — The subject equipment shall be acceptance tested to demonstrate compliance with the technical requirements of this specification (3.0).

4.2 Acceptance Tests. — As required by the "Statement of Work, Goldstone Teletype Multiplex (Sections 3.2.3.4 and 3.2.4.4)," this equipment shall be subjected to acceptance testing at the contractor's facility and again, following installation, at JPL facilities, both series of tests shall be observed by cognizant JPL engineers.

4.3 Test Conditions. — Acceptance tests at the contractor's facility shall be conducted on two fully operational teletype multiplex terminals connected back-to-back.

Acceptance tests at the JPL facilities shall be conducted on two fully installed and operational teletype multiplex terminals connected over two (2) carrier-derived voice-frequency channels on the Western Union Type MLD-4 microwave system provided for this purpose.

4.4 Test Methods. — The contractor shall prepare test procedures for each test to be required. All test procedures will be required to carry the written approval of the cognizant JPL engineer before performance of tests (Statement of Work, Section 3.2.1.2).

4.5 Test Equipment. — The contractor shall propose (4.4) and provide, for the duration of the test program, all specialized test equipment required in the performance of the acceptance tests. This shall not, however, preclude the use of the required integrated test facilities (3.5) and shall, in fact, provide the opportunity to demonstrate the usefulness of the test facilities.

4.6 Tests

4.6.1 Initial Acceptance Tests. — The following tests shall be performed at the contractor's facility as a prerequisite to type acceptance and approval for delivery:

4.6.1.1 Information Rate. — Demonstrate the required capability (3.2.7) while operating at 100 wpm and using the lowest and highest subcarrier frequency channels in each of the two (2) line equipment channels.

4.6.1.2 Bias Distortion. — Demonstrate compliance with the requirement (3.2.8) using the lowest subcarrier frequency channel in each of the two (2) line equipment channels and while operating at 100 wpm.

4.6.1.3 Bias Variation. — Demonstrate compliance with the requirement (3.2.9) using a representative channel.

4.6.1.4 Bias Correction. — Demonstrate compliance with the requirement (2.2.10) using a representative channel.

4.6.1.5 Alarm Supervision. — Simulate all functional failures (3.4.1) to demonstrate all required alarm supervision (3.4.2).

4.6.1.6 Test Equipment. — Demonstrate compliance with the requirements (3.5.1) of capability of test equipment.

4.6.1.7 Patching Facilities. — Demonstrate compliance with all requirements (3.5.2).

4.6.2 Final Acceptance Tests. — The following tests shall be performed at the JPL facilities following installation as a prerequisite to formal acceptance of the operating subsystem:

4.6.2.1 Information Rate. — Demonstrate the required capability (3.2.7) by operation at 100 wpm, half-duplex, over each subcarrier channel.

4.6.2.2 Bias Distortion. — Demonstrate compliance with the requirement (3.2.8) at 100 wpm in each subcarrier channel in each direction of transmission.

4.6.2.3 Alarm Supervision. – Simulate all functional failures (3.4.1) to demonstrate all required alarm supervision (3.4.2).

4.6.2.4 Patching Facilities. – Demonstrate compliance with all requirements (3.5.2).

4.7 Rejection and Resubmittal. – Equipments not meeting the minimum specified requirements (3) shall be rejected and returned to the contractor. Before resubmittal, full particulars concerning the previous rejection and action taken to correct the defects shall be forwarded to JPL.

5. PREPARATION FOR DELIVERY

Not applicable.

APPENDIX K

STANDARD SFOF OPERATIONAL COMMUNICATION SPECIFICATION

INSTALLATION STANDARD SPECIFICATION

1. SCOPE

1.1 This specification covers the general requirements for the installation of electric and electronic systems and equipment in the JPL SFOF.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification.

3. REQUIREMENTS

3.1 Requirements Departure. - Any departure from the requirements of this specification shall be considered a deviation and shall be submitted in writing to the JPL Cognizant Engineer for approval.

3.2 Installation. - The installation of electric and electronic systems and equipment shall be based on the following considerations:

a. Reliability

b. Simplicity of Operation

c. Ease of Maintenance

d. Minimum Resources Cost

e. Minimized need for new, unique, or complex operational support facilities.

f. Maximum safety of personnel and equipment

3.2.1 Reliability - The reliability required of the installation of electric and electronic systems and equipment shall be that which is necessary to achieve the required reliability of the individual subsystem and of the overall systems.

3.2.1.1 Equipment and System Performance - Every consideration shall be given to the installation of equipment and systems to assure a sufficient margin of safety above the minimum required performance consistent with the state-of-the-art and the system reliability requirements to accommodate possible degradation of performance due to operation, environment, aging, maintenance, and testing variations.

3.3.2 Maintainability

3.2.2.1 Maintenance - Ease of maintenance shall be a prime objective for the installation of electronic equipment. Ease of maintenance shall be consistent with the expected life and the maintenance requirements of the installed items.

3.2.2.2 Interchangeability - All parts having the same manufacturer's part number shall be functionally and dimensionally interchangeable.

3.2.2.3 Accessibility - Insofar as practicable, items requiring routine service checking, adjustment, or replacement shall be made readily accessible without teardown of the installation or equipment.

3.2.3 Protection - Protection shall be provided against physical damage such as may be caused by abrasion, mechanical loads, dust and dirt accumulation, etc. Electrical connections shall be protected from foreign objects.

3.2.4 Safety - The installation of equipment shall provide maximum convenience and safety to personnel while installing or interchanging a complete equipment assembly or major assembly thereof and during periodical and corrective checkout and maintenance. Protection shall be provided to prevent personnel from accidentally coming in contact with voltages in excess of 50V.

3.3 Equipment Placement - Equipment units shall be located in accordance with layout drawings provided by JPL.

3.3.1 Clearance - Clearance shall be in accordance with the installation-clearance drawing for the equipment. Where no drawing exists, the clearance shall be not less than the maximum envelope dimensions shown on the drawing for the equipment, plus adequate additional clearance to allow for maintenance, removal and replacement, proper ventilation, and vibration excursions.

3.3.1.1 Shock-Mounted-Units - The envelope determined by the maximum movement of shock-mounted units shall clear surrounding structures, and the maximum envelope of adjacent shock-mounted equipment, by at least 1/8 inch. Shock-mounted units shall not be mounted or installed in any manner other than that for which the shock mounts are designed. Cables shall be of sufficient length to permit proper operation of shock mounts.

3.3.1.2 Ventilation, Cooling, and Heating - When required, space shall be provided around equipment for adequate ventilation, or provisions shall be made for the use of forced cooling, heat sinks, or heating to maintain the operating temperature within design limits.

3.3.1.3 Adjustment Provision - Adequate space shall be provided for adjustment of controls and for pertinent tuning and adjustment by the operator while the equipment is operating.

3.4 Precautionary Measures - Precautionary measures shall be taken when installing electric and electronic equipment so that:

a. This equipment will not cause damage to or be damaged by other equipment, wiring, cabling, ducting, or plumbing.

b. This equipment will not adversely affect the operation of other equipment.

c. The hazard of accidentally energizing or interfering with other circuits, is minimized.

d. Equipment is not located below drip points and tube fittings carrying fluids unless adequate protection is provided.

e. Supporting members, brackets, racks, cable clamps, screws, et cetera, required for mounting the equipment are adequate to carry the units mounted thereon under all normal operation and maintenance conditions.

3.4.1 Mounting of Assemblies - Assemblies shall be fastened to their mounts with sufficient strength to hold the assembly under all design conditions and to withstand such incidental abuse as can be expected under normal service and maintenance conditions. Positive-lock and quick-disconnect devices shall be used where they are advantageous and reliable.

3.4.2 Mounting Hardware - Mounting screws and bolts of suitable strength shall be used for mounting electric equipment and electronic equipment racks. Whenever the undersurface of the mounting is inaccessible, nut plates or other similar means of attachment shall be used. Self-tapping screws shall not be used for mounting equipment or making electrical connections.

3.5 Wiring, Cables, and Connectors - Interconnecting wiring, cables, and connectors shall be installed in accordance with the individual electronic equipment interconnecting wiring diagram or cable diagram, or both.

3.5.1 Selections - Wires and cables shall be of types that are suitable for the application as specified for the system or equipment being installed.

3.5.1.1 Minimum Wire and Cable Size - Wires and cables shall be of such cross section and temper as to provide ample and safe current-carrying capacity and mechanical strength. In general, wire and cable shall be not smaller than AWG-22. When it can be demonstrated that the use of smaller wire and cable will result in no loss of performance and reliability and at the same time produce benefits, such as reduction in weight or improved accessibility, smaller wires or cables may be used if approved by the JPL Cognizant Engineer. This provision is made specifically to permit the use of smaller wires or cables in bundles having a large number of wires or cables and having adequate support against adverse effects of vibration.

3.5.2 Grounding - Grounds for signal, control, and power circuits and for chassis commons shall be wired separately to designated common ground points.

3.5.2.1 Bonding - Unless otherwise specified, bonding shall be in accordance with MIL-B-5087.

3.5.2.2 Radio Interference - Equipment shall be selected and installed in such a manner as to insure conformance of the complete communication system to MIL-E-6051 or to system requirements when these exceed MIL-E-6051.

3.5.2.2.1 Filters - Radio noise filters shall be installed only when necessary. Capacitor-type filters shall be used in all installations except in special cases where they prove inadequate.

3.5.2.2.1.1 Installation - Unless otherwise specified, filters shall be so installed that they are grounded through their mounting with the grounding surface cleaned and refinished in accordance with MIL-B-5087. The connecting wire between the filtered line and filter shall be as short as practicable, and in no case shall it exceed 4 inches unless filter line leads are adequately shielded to prevent any type of radiation. Filters shall be located as near the interference source as practicable. Mounting on the interference source may be made upon approval of the procuring activity.

3.5.2.3 Voltage Drop - The total impedance of wires and cables and ground return paths shall be such that the potential difference between the point of voltage regulation and the load does not exceed the limits shown in Table I. Nominal system voltages shall be used for establishing the current to be used in determining the voltage drops.

Table I - System Voltages and Allowable Voltage Drops

Nominal System Voltage	Maximum Allowable Voltage Drop	
	Equipment Operation	
	Continuous	Intermittent
28	1	2
115	4	8
200	7	14

3.5.3 Identification

3.5.3.1 Wire and Cable Identification - To facilitate installation, assembly, and servicing each wire and cable installed shall be identified as specified herein. The identity of internal wiring of JPL-furnished property shall not be altered by the contractor. The identification of wires and cables shall be accomplished by distinctive color coding or by a combination of letters and/or numbers (wire identification code) marked on the installation wiring diagram and imprinted on the cable. In the latter case, the following requirements for identification shall apply:

a. Assignment of the cable identification code for wires or cables shall be accomplished by the contractor (installing activity).

b. The cable identification code for wires or cables used with JPL-furnished property shall be obtained from the procuring activity.

c. Wires installed to spare pins of connectors, such as potted connectors, shall be identified by the pin designation and wire size; e.g. D-16, a-12, or SMALL A-12.

d. Characters shall be of sufficient size to be legible and of permanent nature. The characters shall be of contrasting color; however, if black insulation is used, white characters are preferred.

e. The method of identification shall not impair the characteristics of the wire or cable.

f. Each wire or cable shall be identified at not more than 15-inch intervals throughout its entire length. Additions and exceptions to this requirement are as follows:

(1) Each wire except those described in 3.5.3.1 shall be marked as follows:

(a) The identification shall be marked on each wire within 3 inches of each termination and junction (except permanent splices) and at intervals of not more than 15 inches everywhere else. The identification shall be so located that shielding, ties, clamps, or supporting devices do not have to be removed in order to read the identification.

(b) The identification shall be printed on the wire.

(2) Wires as follows need not be marked in accordance with 3.5.3.1, but shall be identified as specified.

(a) Each wire that is one of two or more wires and are included within a molded or woven (either metallic or nonmetallic) covering which was molded or woven in place on the wires. Each such cable shall have a sleeve on each end of it on which shall be printed the identification of each wire in the cable, the identification of the termination to which the wire is connected, and when there is any, the means of identifying the wire when the cable is opened (such as color coding).

(b) Each individually shielded wire that has no covering over the shield and is not included in a cable as specified in 3.5.3.1. Each such wire shall have a sleeve on each end of it and at intervals of no more than 6 feet along its length on which shall be printed the identification of the wire.

(c) Each wire and cable that is less than 6 inches long. Such wires and cablesneed not be marked.

(3) For shielded, molded, or sealed cables, the identification code and color (if applicable) of each conductor shall be placed on a sleeve outside the cable. Where not attached to connectors by molding or potting (making non-repairable-type assemblies), each conductor shall be individually marked inside the connector.

3.5.3.2 Coaxial Cable Identification - In addition to the cable identification code, coaxial cables shall be identified within 3 inches of the end which terminates at the equipment to conform to the marking at the receptacle on the equipment. This shall not apply to coaxial cables that terminate in one connector with other wires or cables.

3.5.4 Connectors - Connectors shall be used for joining wires or cables or to connect to equipment when frequent disconnection is required to remove or service equipment, components, or cabling. The number of connectors shall be kept to a minimum.

3.5.4.1 Adjacent Locations - Where similar connectors are used in adjacent locations, wires and cable shall be so routed and supported that improper connections cannot be made. If this requirement cannot be met, adequate marking or identification shall be provided in the form of color coding or tags. Maximum use shall be made of polarizing features or alternate insert positions to prevent misconnections.

3.5.4.2 Drainage - Connectors shall be so positioned as to permit fluids and condensate to drain out of and not into the connector. When connector locations do not allow positioning so that adequate drainage can be obtained, moisture-resistant connectors shall be installed or insulation tubing provided to prevent fluids from running into the connector.

3.5.4.3 Insulation - When not otherwise adequately protected, insulating tubing shall be placed over each wire terminal connection in both plugs and receptacles. The tubing shall extend at least over the end of the terminal a sufficient length to enable tying or otherwise adequately securing. (This requirement does not apply to moisture-resistant type connectors.) Wire identification may be printed on this tubing.

3.5.4.4 Adapters - When not otherwise adequately supported, open wiring attached to connectors shall be supported by adapters or by other approved means. Tightening the adapters or connectors shall cause no strain in cables or their connections. Adapters for special and miniature connections shall anchor the wiring securely under all conditions of stress or vibration.

3.5.4.5 Spares - Connectors shall contain a minimum of 10% (or one) spare terminals, whichever is the greater. Each spare terminal shall be wired to a spare lead in the associated cable. Spare leads shall be sized and typed as far as possible in proportion to the sizes and types of the active leads provided in the cable.

3.5.5 Splices - Splices shall be held to a minimum. Uninsulated splices shall be covered with suitable insulating tubing. The tubing shall extend at least 1/2 inch over each end, provide a snug fit, and be held securely in place. Splices shall be staggered to prevent shorts due to puncturing the insulation and to prevent excessive enlargement of the bundle.

3.5.5.1 Permanent Splices - Permanent splices of a type approved by the procuring activity may be used for final assembly of subassemblies.

3.5.5.2 Disconnect Splices - Approved disconnect splices may be used to facilitate removal of individual wires in nonvital circuits only upon specific approval of the JPL.

3.6 Junctions - Junctions should be kept to a minimum consistent with final assembly requirements. Only approved devices, such as solderless-type terminals, terminal blocks, connectors, permanent splices, and feed-through bushings shall be used for cable junctions. Reliability factors, maintenance factors, and manufacturing procedures shall be considered in determining the need for and the type of device.

3.6.1 Protection - Where required, protection may be provided by covering the junctions, by installing them in junction boxes, and by locating them in such a manner that additional protection is not required.

3.6.1.1 Hoods - Terminal nipples or suitable insulating hoods may be used to provide the required protection on terminal lugs and studs.

3.6.1.2 Nonmetallic Covers - Nonmetallic junction covers, such as fabric or plastic, shall maintain a high dielectric resistance and shall not absorb fluids. They shall be so installed as to allow for drainage, not interfere with mechanical movements, and in such manner that metal fasteners cannot cause short circuits. Nonmetallic covers in proximity with high-temperature equipment, such as resistors, shall withstand the maximum temperature without damage.

3.6.2 Installation - Electrical junctions shall be installed so that they are adequate both mechanically and electrically. They shall not be subject to mechanical strain nor used to support insulating materials. Junctions shall not depend upon insulators under compression for maintaining the connection tightness.

3.6.2.1 Spacing - Electrical junctions shall be adequately spaced to prevent detrimental leakage currents between circuits under the specified environmental conditions to which the equipment will be subjected. Suitable insulating barrier material may be used to provide necessary creepage distance.

3.6.2.2 Sensitive Circuits - Sensitive circuits shall be kept separate from other circuits at junctions when the proximity of such circuits has a detrimental effect on the performance of the equipment or system. This may be accomplished by using separate connectors for the sensitive circuits and by having at least one grounded terminal stud between sensitive circuits and other circuits on a common terminal block.

3.6.2.3 Accessibility - Junctions, other than permanent splices, shall be accessible for inspection and maintenance with a minimum of disturbance to other items and with the use of a minimum number and variety of special tools.

3.6.3 Conductivity - Electrical junctions shall be made in such a manner that the conductivity at junctions will be suitable for the circuit.

3.6.3.1 Disconnect Junctions - Disconnect-type junctions, such as connectors and disconnect splices, shall have a conductivity of not less than that of an equivalent length of cable equal in size to that making the junction.

3.6.3.2 Bolted Junctions - Bolted and permanent-type junctions, such as terminal blocks, shall be made in such a manner that the conductivity at the junctions will be not less than that of an equivalent length of cable equal in size to that making the junction.

3.6.4 Insulation - Insulation tubing shall be placed over terminals where necessary to provide electrical and mechanical protection. Provisions shall be made for keeping the tubing in place. Wire identification may be printed on this tubing.

3.6.5 Terminal Blocks - Terminal blocks shall conform to MS25123 for junctions of wires and cables requiring infrequent disconnection or the joining of more than two wires and cables to a common point. The number of wires and cables connected to any one stud shall be limited to four. The terminals shall be so installed that tightening the nut on the stud will not deform the stud. Equipment terminal studs may be used for joining wire and cable terminal lugs wherever they are suitable.

3.6.6 Junction Boxes - Junction boxes, when required, shall be placed in an accessible location to facilitate testing and shall be adequately identified in a manner to facilitate maintenance.

3.6.6.1 Electrical Circuit Separation (Design Objective) - Only those circuits necessary for interconnecting the applicable electronic equipment shall terminate or be routed through the junction boxes provided for electronic equipment. Unassociated electrical and similar circuits shall not enter these junction boxes.

3.6.6.2 - Nonmetallic or metal junction boxes lined with insulation material are preferred to unlined, metal boxes in order to lessen the possibility of shorting between connections and the box.

3.6.6.3 Construction - Junction boxes shall be of suitable construction to house junctions, wiring devices, and equipment. The inside shall be of a light color to facilitate inspection and repair.

3.6.6.4 Identification - Junction boxes shall be externally identified to facilitate correlation of the box with the wiring diagrams.

3.6.6.5 Installation - Junction-box wires and cables shall be adequately supported at convenient intervals to:

a. Provide neat and orderly arrangement

b. Provide ease of inspection and maintenance

c. Provide relief of strain on terminals

d. Minimize possibility of faults

e. Prevent vibration from damaging wires and cables or terminals.

3.7 Routing - Wiring shall be routed to:

a. Provide reliability

b. Not be source of interference or coupling between systems

c. Prevent malfunctioning of equipment by induction

d. Provide accessibility for inspection and maintenance

e. Minimize the possibility of damage.

3.7.1 High-Temperature Equipment - Wires and cables shall be kept separate from high-temperature equipment, such as resistors, exhaust stack, and heating ducts, to prevent cable insulation deterioration.

3.7.2 Additional Protection - Electrically unprotected power and distribution circuit wires, cables, and buses shall be given particular mechanical protection, such as in the form of extra insulation. Bus centers shall be located within insulated enclosures so isolated as to prevent a line-to-ground or phase-to-phase short circuit that would disrupt the electrical power system.

3.7.3 Slack - Excess slack shall not be provided in wires or cables, except for drip loop and service requirements. However, enough slack shall be provided to:

a. Permit ease of maintenance including connector replacement

b. Prevent mechanical strain on the wires or cables, junctions, and supports

c. Permit free movement of shock- and vibration-mounted equipment.

3.7.4 Radius of Bend - The minimum radius of bend for power distribution wires or cables shall be 10 times the outside diameter, except that at terminal strips where the cable is suitably supported, the radius may be 3 times the diameter of the cable. Where it is impracticable to install these wires and cables within the radius requirements, the bend shall be enclosed in insulation tubing.

3.7.4.1 Coaxial Cables - For coaxial cables, the minimum radius of bend shall not unduly affect the characteristics of the cable.

3.7.5 Wires and Cables Near Moving Parts - Wires and cables attached to assemblies where relative movement occurs at hinges and rotating pieces shall be installed or protected in such a manner as to prevent deterioration of the wires and cables caused by relative movement of the assembly parts. This deterioration includes abrasion of one wire or cable upon the other, and excess twisting and bending. As a design objective, bundles shall be installed to twist instead of bend across hinges.

3.7.6 Support - Wires and cables shall be supported by cushion clamps, grommets, or other approved devices at intervals of not more than 24 inches, except when contained in ducts or conduits.

3.7.6.1 Size and Type - Supporting devices shall be of a suitable size and type so that the wires and cables will be held securely in place without damage to the insulation.

3.7.6.2 Wire and Cable Installation - Wires and cables shall be properly supported and bound to:

a. Prevent chafing

b. Secure wires and cables where routed through bulkheads and structural members

c. Fasten wires and cables in junction boxes, panels, and bundles for proper grouping and routing

d. Prevent mechanical strain or work hardening that would tend to break the conductors and connections

f. Facilitate reassembly to equipment terminal boards

g. Prevent interference between wires and cables and other equipment.

3.8 Limitations

3.8.1 Tapes - Tapes that will dry out in service, produce chemical reaction with cable insulation, or absorb moisture shall not be used.

3.8.2 Insulation Tubing - The use of insulation tubing to protect wires and cables from abrasion, chafing, exposure to fluids, and other conditions that may affect cable insulation shall be minimized. Nonrigid insulation tubing shall not be used for support of wires and cables.

3.8.3 Moisture-Absorbent-Type Materials - Moisture-absorbent-type materials shall not be used as a fill for clamps or adapters.

3.8.4 Bundling - Wires and cables shall not be tied nor fastened together in conduit or insulation tubing.

3.8.5 Cable Supports - Cable supports shall not restrict the wires or cables in such manner as to interfere with operation of shock mounts.

3.8.5.1 Tape and Cord - Tape and cord shall not be used for primary support.

3.9 Conduit

3.9.1 Metallic Conduit - Upon approval of the procuring activity, metallic conduit may be used in the installation only where necessary to protect wiring or to facilitate maintenance in inaccessible portions of the building. Metallic conduit shall be used, when necessary, between equipment and its related radio-noise filter unit. Metallic conduit may be used for shielding to meet the requirements of MIL-E-6051, subject to approval of the procuring activity.

3.9.1.1 Flexible Conduit - Flexible conduit shall be used only when the use of rigid metallic conduit is impracticable.

3.9.2 Nonmetallic Conduit - JPL-approved nonmetallic conduit, such as insulation tubing, may be used for electrical and mechanical protection of wiring, but shall not be installed in greater amounts than necessary.

3.9.2.1 Types - Nonmetallic conduit shall be of a material satisfactory for the ambient temperature encountered.

3.9.3 Conduit Installation - Conduit shall be so installed as to withstand vibration and normal service abuse.

3.9.3.1 Support - Conduit shall be so installed as to relieve strain on the ferrules.

3.9.3.2 Drainage - Where practicable, conduit shall be so installed that fluids or condensate will not be entrapped. Suitable drainage holes shall be provided at the low points, except for metallic flexible conduit or when installed in locations which may permit fluids to enter the conduit through such holes. Burrs shall be removed from drainage holes and conduit terminations. Where drain holes cannot be provided, provisions shall be made to prevent entrapment of fluid in the conduit.

3.9.3.3 Grounding - Grounding of metallic conduit shall be in accordance with MIL-B-5087.

3.9.3.4 Radius of Bends - Conduit and conduit fitting bends shall not cause chafing of cables.

3.9.3.5 Diameter - The group of wires and cables to be installed in the conduit shall be bundled together and the maximum diameter measured. The maximum diameter shall not exceed 80% of the internal diameter of the conduit.

3.10 Drawings

3.10.1 Wiring and Interconnection Diagrams - Wiring and interconnection diagrams shall be prepared and submitted to JPL as specified herein.

3.10.1.1 Preliminary Block Diagrams and Schematics - Preliminary block diagrams and schematics that show each electrical and electronic circuit shall be provided for each system. Presentation of circuits in straight line (elementary) form is acceptable and multiple sheets may be used.

3.10.1.2 Schematic and Interconnection Diagrams - Schematic and interconnection diagrams, and any revisions thereto, for each system shall be provided. These diagrams shall be on multiple sheets or in book form.

3.10.1.2.1 Approval of Schematic and Interconnection Diagrams - Schematic and interconnection diagrams shall be submitted to the procuring activity for approval prior to delivery and subsequent to mockup approval (See 4.3).

3.11 Workmanship - Details of workmanship shall be in accordance with high-grade, electrical wiring, and equipment installation practice and of such quality as to insure safety, proper operation, and service life. Details of workmanship shall be subject to the inspection and approval of the procuring activity.

3.11.1 Loose Parts - All loose parts, chips, scraps, excess hardware, et cetera, shall be removed from the equipment.

4. QUALITY ASSURANCE PROVISIONS

4.1 Supplier's Responsibility - The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to JPL. Inspection records of the examination and tests shall be kept complete and available to JPL as specified in the contract or order. JPL reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of Tests - The inspection and testing of wiring installation shall be classified as acceptance tests.

4.3 Approval of Schematic and Interconnection Diagrams - Prior to the scheduled date of delivery of the equipment, schematic and interconnection diagrams shall be submitted to the procuring activity for approval as specified in 3.10.1.2.1.

4.4 Wiring Mockup - Unless otherwise specified prior to delivery of the equipment, the contractor shall conduct a wiring mockup for inspection by the procuring activity. At this mockup, the contractor shall demonstrate typical wiring installations and specific wiring practices for which deviations are required.

4.5 Individual Tests - Functional tests shall be conducted by the contractor on each equipment to insure proper continuity of all electrical and electronic circuits and proper operation of all electrical and electronic equipment.

5. NOTES

5.1 Intended Use - The installation of wiring and wiring devices covered by this specification is intended to provide satisfactory interconnection of electric and electronic communication equipment.

5.2 Installation Data (CFE) - Installation requirements for contractor-furnished equipment will be obtained from data prepared by the electronic-equipment contractor.

5.3 Installation Data (JPL-FE) - Installation data for JPL-furnished equipment will be obtained from the procuring activity.

5.4 Definitions - For the purposes of this specification, the following definitions will apply:

a. Wires, electrical - A single, metallic conductor of solid, stranded, or tinsel construction designed to carry current in an electrical circuit; it may be bare or insulated, but does not have a metallic covering, sheath, or shield.

b. Cable, power, electrical - Two or more insulated conductors, solid or stranded, contained in a common covering; two or more insulated conductors twisted or molded together without common covering, or one insulated conductor with a metallic covering shield or outer conductor.

c. Wiring - An installation or the installing of wires and cables.

d. Wiring devices - The accessory parts and materials that are used in the installation of wiring, such as terminals, connectors, junction boxes, conduit, clamps, insulation, and supports.

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